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SELF PROPELLED SPOKE WHEEL NITROGEN APPLICATOR FOR RICE RESIDUE MULCHED WHEAT CROP

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Abstract: In order to reduce nitrogen losses sustained in broadcasting of urea under high rice straw mulched wheat crop and to enhance crop yield, a self propelled spoke wheel nitrogen applicator for injecting nitrogen in liquid form beneath the soil surface was designed, developed and evaluated under actual field conditions. The machine comprised four sets of spoke wheel having radial injectors attached to a distribution hub with inline mounted flow control valve and cut-off system. Constant supply of liquid urea to the distribution hub by means of a piston pump produced pressure adequate to expel urea solution through the flow control valve as it opened. The opening and closing of flow control valve was regulated through a specially designed lever and stationery cam. The average field capacity and efficiency of the machine were found to be 0.36 $ha \cdot h^{-1}$ and 88.9%, respectively. Yield and nitrogen use efficiency (*NUE*) of wheat crop fertilized with spoke wheel nitrogen applicator was 20 and 47 % respectively higher than that of broadcasting method of nitrogen application. Lower nitrogen accumulation in mulch and higher nitrogen uptake in wheat crop indicated reduced nitrogen losses in case of point injected nitrogen application over broadcasting. Hence, spoke wheel nitrogen applicator acquires a promising option not only for enhancing crop yield but also environment protection.

Key words*: spoke wheel nitrogen applicator, broadcasting, rice straw mulch concentration, nitrogen use efficiency, nitrogen uptake, yield*

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INTRODUCTION

The sustainable food security for ever-increasing human population along with environmental protection and conservation of natural resources have emerged as the prime concerns for the global agriculture. Green revolution changed Indian agriculture scenario and Punjab had major contribution in this revolution. Use of fertilizers, pesticides, insecticides, high yielding varieties, and advanced machines helped in agriculture growth. Rice-wheat cropping system became popular in Punjab [8]. The developments of machinery like 'Happy seeder' for simultaneously mulching rice straw while sowing wheat have provided the option of surface applied rice residue rather than burning and incorporation [7]. Mulched rice residue result in less N immobilization and also provide benefits viz. conservation of soil, water and weed suppression. No difference in grain yield and biomass production has been reported for direct drilling of wheat in the rice stubbles compared to traditional method of sowing. Some field studies from India and China with reduced or no-till wheat and other cereal crops revealed that mulching rice residue increased crop productivity [1].

The rapid adoption of mulch-tillage system in wheat after rice has led to increased demand of nitrogenous fertilizer (urea) due to inefficient and improper application method. About 40% of the N fertilizer applied to irrigated wheat is only utilized by the plants due to inefficiency in application (wrong method or timing of application) [9]. The mulch retained the broadcasted fertilizer granules and ammonia volatilization losses enhances, leading to a low N efficiency. The presence of crop residues on the soil surface containing urea increases the rate of urea hydrolysis, thus increasing the potential for ammonia volatilization in no-till systems. Where urea or urea-based fertilizers are surface applied, particularly in the presence of organic residues, crop yields are often reduced. There have been reports in the literature that suggests that higher nitrogen rates are required to crops sown in straw mulch because fertilizer use efficiency of the plants is limited in such conditions and crop becomes deficient of nitrogen at recommended rate of fertilizer application [3].

Therefore, a new innovation to overcome the problem of improper and inefficient top dress nitrogen application in high residue mulched no-till wheat in the *RW* system is warranted. An approach that has not been well explored is the use of point injection of urea in mulch seeded wheat. The objective of this study was to design and develop a spoke wheel nitrogen applicator for application of liquid urea in rice straw mulched wheat crop.

MATERIAL AND METHODS

The self-propelled spoke wheel nitrogen applicator was designed and developed based on its required function. The design of nitrogen (liquid urea) applicator is based on the idea that using a narrow spoke wheel with injectors on its periphery shall work as liquid urea applicator in straw mulched wheat crop. The cone shaped injector on spoke wheel periphery would penetrate the straw mulch more easily by the weight of the machine and require less vertical force. To increase further penetration of liquid urea in the soil and also to prevent clogging of injectors, the liquid urea needs to be applied at some pressure.

Keeping in view conceptual and functional design, a prototype model of nitrogen (liquid urea) application mechanism (Fig. 1) was fabricated and evaluated under simulated conditions for its working performance. The water was applied at variable operating pressure ranging from 2.0 to 4.0 kg·cm^{-2} with sprayer pump. It was observed that operating pressure $\leq$ 2 kg·cm^{-2} leads to clogging of injectors and insufficient depth of injection while operating pressure $\geq$ 3.5 kg·cm^{-2} leads to leakage and excessive disturbance of soil. The prototype model worked satisfactorily at operating pressures ranging from 2.0 to 3.5 kg·cm^{-2}. The average depth of injection was found varying from 25.80 -36.50 mm at operating pressure range of 2.0 - 3.5 kg·cm^{-2}. The average spread diameter of wetted soil was observed in the range of 75.90 - 104.70 mm. Observing the satisfactory performance of prototype model of nitrogen applicator, a 4-row self propelled spoke wheel nitrogen applicator prototype was conceived and developed.

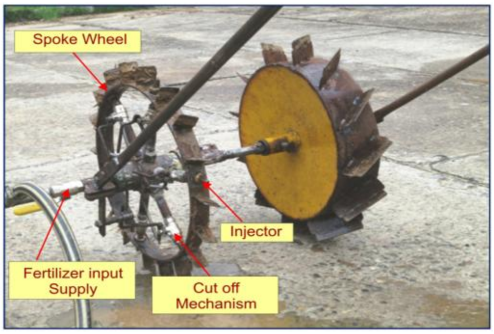

Figure 1. View of prototype model of nitrogen (liquid urea) applicator

Constructional details of the machine. The spoke wheel nitrogen applicator was developed as a rear mounted attachment to self propelled engine unit (Fig. 2). The basic components of the machine were 4 sets of spoke wheel with fertilizer metering and cut-off mechanism, a pump, a fertilizer tank and a pressure gauge. The function of each part and development are as follows.

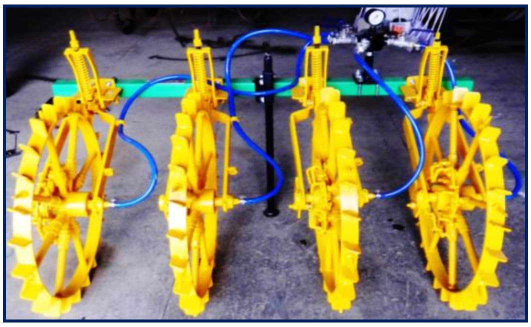

Figure 2. View of self propelled spoke wheel nitrogen applicator

Main frame. The tool bar served as a support to attach the spoke wheel assembly to a prime mover. The tool bar assembly comprised two support arms rotation secured at one end to the spoke wheel assembly and another end to a support plate. The support plate was used for attachment of the implement to a tool bar by two U-clamps. The four units of spoke wheel nitrogen applicator were clamped on the tool bar at uniform spacing of 400 mm between consecutive spoke wheels. The spring biased joint used a coil spring to keep the support arm in a downward direction to prevent skidding and permitted the support arm to move upward if spoke wheel encountered any obstruction.

Spoke wheel. A set of four spoke wheels were mounted on the frame. The spoke wheel assembly included a fertilizer metering and cut-off mechanism and a circular rim that is concentric with the distribution hub. The circular rim of 640 mm diameter was welded with trapezoidal shaped lugs on the periphery for the positive rotation under mulch conditions. The rim served as a means for bracing and stabilizing the position of the spokes with respect to distribution hub and controlling depth of penetration in the soil.

Fertilizer Metering and Cut-off mechanism. It consisted of a distribution hub acting as a reservoir in which water dissolved urea was supplied longitudinally from one side and exit tangentially out of spokes mounted on the periphery of the distribution hub. The distribution hub mounted on an axle with two ball bearings at both ends and acted as a rotary valve for metering and supplying liquid urea from the main supply to the spokes fitted on the periphery of the distribution hub. An inline mounted flow control valve was provided to regulate the liquid urea flow between distributor and injector. Each flow control valve fitted in spoke assembly was provided with independent cutoff lever. A specially designed crank lever regulated the opening and closing of flow control valve. The load arm of the lever was attached with a helical tension spring, which kept the flow control valve in closed position. The effort arm of the crank lever was actuated by a stationery cylindrical cam fitted tangentially on a plate with the spoke wheel. The cam was so designed that it operated the cutoff lever for 30° of rotation of spoke wheel as an injector touches the soil surface. With the rotation of spoke wheel, the effort arm of the lever strikes with the cam and is pushed back; which resulted into the opening of the flow control valve. As the lever arm passes the cam, the flow control valve comes to its closed position by the tension of the spring.

Pump. A double cylinder piston pump was used for the supply of liquid urea at constant pressure to the distribution hub. A control valve assembly was provided to regulate the pressure and bypass the extra quantity of liquid fertilizer to the fertilizer tank. The pump could develop maximum pressure up to 28 $kg\cdot cm^{-2}$ at 950 min^{-1} with suction capacity of 13 $l\cdot min^{-1}$.

Fertilizer Tank. A mild steel tank having capacity of 100 L was used to store the liquid urea solution. The urea solution is fed to the pump from the tank by pump and at the open end of the suction pipe a strainer was provided to prevent the flow of foreign materials with the liquid urea solution. The open end of the bypass pipe was connected with the tank so that the liquid urea solution which was not utilized by the spoke wheels could go back to the tank. The fertilizer tank was sufficient for liquid urea application of 480 m^2 area.

Pressure Gauge. A pressure gauge was provided to check the operating pressure at which liquid urea solution has to be delivered to the distribution hub by the main supply. A control valve was provided in each supply line to maintain the desired flow rate.

Prime-mover. A diesel engine of 4.48 kW was selected as prime mover for operating the spoke wheel nitrogen applicator. It had two narrow rubber wheels which were powered from the engine through gears and chains. The ground clearance of the machine was kept 500 mm taking in view the crop height at the time of fertilizer application. A third wheel was provided at the rear to act as transport wheel. A provision was made to adjust the track width from 900 to 1050 mm. A pump operating lever was provided on the handle to operate the pump during the nitrogen (liquid urea) application in the field. A transmission clutch lever was also provided on the handle to control the transmission system of the machine. An accelerator lever regulated the forward speed of the machine.

Field evaluation of the machine. The developed machine was evaluated in straw mulched wheat crop twice during the crop season. The operating pressure of pump was fixed at 3.0 $kg \cdot cm^{-2}$ and machine was operated at a forward speed of 2.5 $km \cdot h^{-1}$ in the field. At this operating pressure and forward speed, the machine delivers 2095 $lit \cdot ha^{-1}$ solution of urea [2]. Accordingly, the solution of urea was prepared by mixing required dose of urea with water. The fertilizer tank was filled with solution of urea. A hand lever has been provided for the on/off operation of the pump. With the engagement of lever, the pump starts the supply of urea solution to the spoke wheel. During rotation of the spoke wheel, it carries urea solution into the distribution hub and delivers them to the injectors through spokes. Fertilizer applicator delivers the urea solution at 250 mm spacing along the row and 400 mm row spacing (alternate row).

An experiment was laid out in a factorial randomized block design with three replications comprising of six treatments with two levels of rice straw mulch concentration and three levels of methods of fertilizer application. The plots size of each plot was 14 x 12 m^2. Following were the treatments:

A. Methods of Nitrogen Application (3 methods)

M_1: Application of N with developed machine (0 + ½ N after 1^{st} irrigation + ½ N after 2^{nd} irrigation)

M_2: Broadcasting of N as per University package of practice (½ N during sowing + $1/4^{th}$ N after 1^{st} irrigation + $1/4^{th}$ N after 2^{nd} irrigation)

M_3: Broadcasting of N general practice followed by farmers using 'Happy seeder' (0 + ½ N before 1^{st} irrigation + ½ N before 2^{nd} irrigation)

B. Rice Straw Mulch Concentration (2 levels)

L_1: Low straw mulch concentration (4.6 $t \cdot ha^{-1}$)

L_2: High straw mulch concentration (8.0 $t \cdot ha^{-1}$)

Constant Parameters: Wheat directly sown in combine harvested paddy field using 'Happy seeder'.

All the experimental plots were sown uniformly using 'Happy Seeder' under two rice straw mulch concentration conditions. Wheat (variety *PBW*-621) was sown on November 9, 2012 and all the plots received a basal dose of 26 $kg \cdot P \cdot ha^{-1}$ and 25 $kg \cdot K \cdot ha^{-1}$ prior to sowing. Fertilizer nitrogen 110 $kg \cdot N \cdot ha^{-1}$ was applied as per treatments of methods of N application. In all M_1 treatments, nitrogen fertilizer (water dissolved urea) was point injected in two splits using spoke wheel nitrogen (liquid urea) applicator (Fig. 3). In M_2 treatment, recommended dose of urea was broadcasted in three splits after 4-5 days of irrigation while in M_3 treatment, recommended dose of urea was broadcasted in two splits before the application of irrigation. All other practices for growing wheat crop were followed as recommended by Punjab Agricultural University, Ludhiana.

Figure 3. Real and field operational view of self propelled spoke wheel nitrogen applicator

RESULTS AND DISCUSSION

The Average operating time, field capacity and operation efficiency of the self-propelled spoke wheel nitrogen applicator were 2.78 $h{\cdot}ha^{-1}$, 0.36 $ha{\cdot}h^{-1}$, 88.9%, respectively. The fuel (High speed diesel) consumption of self propelled nitrogen (liquid urea) applicator was 0.980 $lit{\cdot}h^{-1}$.

Effect of Methods of Nitrogen Application on N Uptake and yield attributes.

Total Plant N Uptake. N-uptake is interplay of biomass production and N-concentration. Highest total plant N uptake at maturity (121.44 $kg{\cdot}ha^{-1}$) occurred in case of M_1 method of N application at high straw load while lowest N uptake (76.16 $kg{\cdot}ha^{-1}$) was observed in case of M_2 method of N application at high straw mulch concentration (Fig. 4). Total plant N uptake did not differ at different straw mulch concentration with M_1 method of N application while plant N uptake differ significantly at different straw mulch concentration with M_2 and M_3 methods of N application.

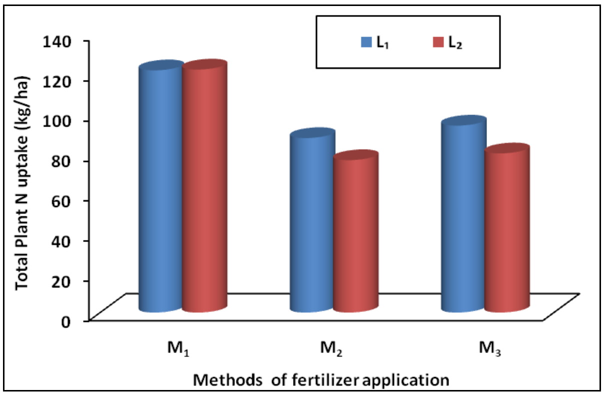

Figure 4. Effect of methods of nitrogen application on plant N uptake

*Nitrogen accumulation in straw mulch***.** Nitrogen accumulation in straw mulch indicating nitrogen loss tended to be similar among treatments at the time of sowing. The

N accumulation in straw mulch in case of broadcast (M_2 & M_3) methods of N application increased or remained same during the crop growing season whereas it showed decreasing trend in case of M_1 method of N application. At 70 *DAS*, mean N accumulation in mulch was significantly lower in case of M_1 than M_3 and M_2 methods of N application. But no significant difference of N accumulation in mulch among M_2 and M_3 methods of N application was observed at this stage. At the time of crop maturity, the N accumulation in straw mulch in case of M_1 method of N application was significantly lower than that of M_2 and M_3 methods (Fig. 5). The lower accumulation of N in straw mulch indicated low nitrogen loss in M_1 method of nitrogen application. This might be due to non contact of nitrogen fertilizer with straw mulch during application which could be coupled with the favourable effect for enhancing the crop yield.

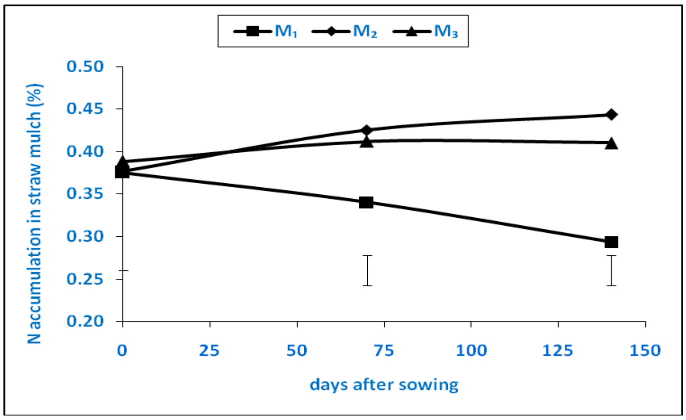

Figure 5. Effect of methods of nitrogen application on N accumulation in straw mulch

Grain Yield and attributes. Methods of N application had significant effect on the number of earhead per m row length (P <0.05), length of earhead (P < 0.05), grain number per earhead (P <0.01), 1000-grain weight (P <0.05) and the grain yield (P <0.01). Mean comparisons showed that point injected nitrogen through spoke wheel nitrogen applicator increased all of the above yield components (Tab. 1). The highest number of earhead per m row length, higher earhead length, higher numbers of grains per earhead resulted for point injected nitrogen (liquid urea) applied by nitrogen applicator (M_1) at recommended dose than other broadcasting treatments (M_2 and M_3) but there were no significant difference of number of grains per earhead among the treatments M_2 and M_3. Similar trends were obtained for 1000 grain weight with highest 1000 grain weight in case of point injected nitrogen application (M_1). The higher 1000 grain yield in case of M_1 might be due to higher nitrogen concentration in plant tissue. The researcher [6] also reported higher 1000 grain weight in case of fertilizer injection as compared to broadcasting method. It can also be observed from the table that significantly higher grain yield for point injected nitrogen application with nitrogen applicator (M_1) than that of broadcasting urea (M_2 & M_3). There were no significant differences of grain yield between M_2 and M_3 treatments of N application. The researcher [4] also observed 15.5% significant higher wheat yield by injection method in comparison with the conventional method (broadcasting).

Nitrogen Use Efficiency (NUE). The NUE in case of urea solution injected with spoke wheel nitrogen applicator (M_1) was 47.1% more than that of broadcasting of urea (M_2) (Fig. 6). Lower wheat *NUE* in broadcasting of urea under straw mulch conditions was due to lesser availability of N to the plant and lower grain yield and higher wheat NUE in nitrogen application with spoke wheel nitrogen applicator may be ascribed to more N uptake and higher grain yield. Based on the result findings, the researcher [5] strongly recommended injection fertilization in case of minimum or zero tillage cereal crops.

Table 1. Effect of different nitrogen application methods on Yield Components

Treatment	*Yield attributes**				
	No of ear-heads per m row length	*Ear-head length [cm]*	*Number of grains per ear-head*	*1000 grain weight [gm]*	*Grain yield [q·ha⁻¹]*
M_1	*97.61a*	*11.00a*	*54.42a*	*42.18a*	*54.23a*
M_2	*86.56b*	*10.10b*	*42.56b*	*39.38b*	*45.28b*
M_3	*93.42c*	*10.33c*	*44.33b*	*39.16b*	*46.92b*

Note: Common letter in the same column are not significantly different at P≤ 0.05 by LSD
**Average values at two straw mulch concentration*

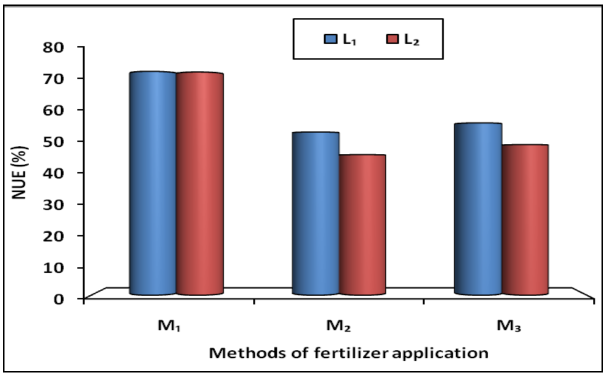

Figure 6. Effect of methods of nitrogen application on nitrogen use efficiency (NUE)

CONCLUSIONS

The developed spoke wheel nitrogen applicator was found efficient and environmentally viable for injection of nitrogen (liquid urea) in straw mulched wheat crop. The point injected nitrogen application in rice straw mulched wheat crop enhanced 20 % grain yield and 47 % nitrogen use efficiency over broadcasting of urea. The lower N accumulation in straw mulch in case of point injected N application through spoke wheel nitrogen applicator indicated the reduced N loss under this system of fertilizer urea application particularly under straw mulched conditions. Significant higher N uptake was observed in case of point injected N application over surface broadcast in the presence of rice straw mulch.

BIBLIOGRAPHY

[1] Bijay Singh, Shan, Y.H., Johnson-Beebout, S.E., Singh, Y., Buresh, R.J. 2008. Crop residue management for lowland rice-based cropping systems in Asia. *Advances in Agronomy*, 98:201–270.

[2] Dixit, J., Mahal, J.S., Manes, G.S., Singh, M. 2015. Development and standardization of nitrogen (liquid urea) application metering mechanism for point injection nitrogen applicator. J. Ag. Eng. 15(4).

[3] Gangwar, K.S., Singh, K.K., Sharma, S.K., Tomar, O.K. 2006. Alternative tillage and crop residue management in wheat after rice in sandy loam of Indo-Gangetic plains. *Soil and Tillage Res,*. 88: 242-252.

[4] Kubesova, K., Balik, J., Sedlar, O., Peklova, L. 2013. The effect of injection application of ammonium fertilizer on the yield of maize. *Sci Agri Bohem,*. 44(1): 1–5.

[5] Kücke, M., Gref, J.M. 2006. Experimental results and practical experiences with the fluid fertilizers point injection fertilization in Europe and potentials to optimize fertilization and to minimize environmental pollution. *Proceeding of 18th World Congress Soil Sci. Pp* 170-22.Philadelphia, Pennsylvania, USA**.**

[6] Sedlar, O., Balik, J., Kozlovsky, O., Peklova, L., Kubesova, K. 2011. Impact of nitrogen fertilizer injection on grain yield and yield formation of spring barley. *Plant and Soil Environ.*, 57 (12): 547–552.

[7] Sidhu, H.S., Singh, M., Humphreys, E., Singh, Y., Singh, B., Dhillon, S.S., Blackwell, J., Bector, V., Singh, M., Singh, S. 2007. The HS enables direct drilling of wheat into rice stubble. *Aus. J. Exp. Agri*., 47: 844-854.

[8] Singh, H., Singh, K., Singh, M., Bector, V., Sharma, K. 2015. Field evaluation of tractor mounted soil sensor for measurement of electrical conductivity and soil insertion / compaction force. *J. Agril. Engg.*, 15(3), 33-42.

[9] Singh, Y., Sidhu, H.S., Singh, M., Humphreys, E., Kukal, S.S., Brar, N. K. 2008. Straw mulch, irrigation water and fertilizer N management effects on yield, water use and N use efficiency of wheat sown after rice. *Proceeding of Permanent beds and rice residue management for rice-wheat systems in the Indo-Gangetic plain*. pp 171-181 Centre for International Agricultural Research, Canberra.

SAMOHODNI APLIKATOR ZA UBRIZGAVANJE TEČNOG AZOTA U USEVU PŠENICE NA USITNJENIM ŽETVENIM OSTACIMA PIRINČA

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Sažetak: Sa ciljem smanjenja gubitaka azota pri ubacivanju uree pod usitnjene žetvene ostatke radi povećanja prinosa, konstruisan je samohodni aplikator za ubrizgavanje tečnog azota pod površinu zemljišta. Mašina se sastoji od četiri kompleta točkova sa paocima i injektorima postavljenim na haubu sa ugrađenim ventilom za kontrolu protoka i isključenje sistema. Konstantan dotok tečne uree do distributera preko klipne pumpe obezbeđen je odgovarajućim pritiskom za izbacivanje rastvora uree kad je kontrolni ventil otvoren. Otvaranje i zatvaranje kontrolnog ventila je regulisano specijalno konstruisanom ručicom. Srednji poljski kapacitet i efikasnost mašine su iznosili 0.36 $ha \cdot h^{-1}$ i 88.9%, redom. Prinos i efikasnost iskorišćenja azota (*NUE*) kod pšenice đubrene ovim aplikatorom azota bili su 20 i 47%, redom, viši nego pri uobičajenom rasturanju azota. Niža akumulacija azota u malču i više usvajanje azota kod pšenice ukazuju na manje gubitke azota kod tačkastog ubrizgavanja azota u odnosu na rasturanje. Tako ovaj aplikator azota predstavlja povoljniju opciju, ne samo za povećanje prinosa nego i za zaštitu okoline.

Ključne reči: *orebreni točak za aplikaciju azota, emisija, koncentracija usitnjene slame pirinča, efikasnost iskorišćenja azota, usvajanje azota, prinos*

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DEVELOPMENT AND EVALUATION OF METERING MECHANISM FOR SOWING OF ONION SEED (*ALLIUM CEPA* L.)

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Abstract: Onion (*Allium cepa* L) is one of the major vegetable crops grown throughout the country. It is widely grown in different parts of the country mainly by small and marginal farmers. Generally, the onion seeds are sown in nursery and transplanted with row to row spacing of 15 cm and plant to plant spacing of 7.5 cm to get optimum yield. The labour requirement in manual transplanting of onion seedlings is as high as 100 - 120 man-days·ha^{-1} as $8.9 \cdot 10^5$ seedlings per hectare are to be transplanted. Because of high requirement and shortage of labor, the area under onion cultivation is low and can be increased by mechanization of this crop. An inclined plate was developed for metering of onion seed. The plate was evaluated on the basis of performance parameters i.e. missing index, multiple index, average seed spacing, quality of feed index, seed rate, seed damage and degree of variation at four forward speeds (1.0, 1.5, 2.0 and 2.5 km·h^{-1}) and three angles of inclination (47^o, 55^o and 62^o) of seed metering plate with horizontal for three cultivars of onion seed (Punjab Naroya (PN), Agrifound Light Red (ALR) and Agrifound Dark Red (ADR)). The missing index increased, whereas multiple index and seed rate decreased with increase in forward speed for all the varieties and each angle of inclination of the inclined plate with horizontal. Considering all the performance parameters, it was concluded that the forward speed should be in the range of 1 – 1.5 km·h^{-1} and an angle of inclination of seed plate should be 55^o with horizontal.

Key words: *seed metering mechanism, onion, inclined plate, direct seeding, vegetable crops, planter, missing index, seed rate, seed spacing, multiple index*

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INTRODUCTION

Onion (*Allium cepa L.*) is one of the major vegetable crop grown throughout the country. It is widely grown in different parts of the country mainly by small and marginal farmers. In Maharashtra and Gujrat, this crop has gained the importance of cash crop rather than a vegetable crop because of its very high export potential. Maharashtra alone contributes 32% of the total national production. Nasik district alone contributes 30-40% of the state's production. In India, Maharashtra is a leading onion whereas the productivity of onion is the highest in Gujarat (25.43 $t \cdot ha^{-1}$) followed by Madhya Pradesh (24.09 $t \cdot ha^{-1}$) and Bihar (24.01 $t \cdot ha^{-1}$) [1]

Generally, the onion seeds are sown in nursery and transplanted with row to row spacing of 15 cm and plant to plant spacing of 7.5 cm to get optimum yield. During onion cultivation, transplanting of seedlings, weeding and harvesting are the most labour intensive operations that are presently done manually in India. The labour requirement in manual transplanting of onion seedlings is as high as 100 – 120 man- $days \cdot ha^{-1}$ as 8.9 lakh seedlings per hectare are to be transplanted [5]. Because of high requirement and shortage of labor, the area under onion cultivation is low and can be increased by mechanization of this crop. Onion harvester being developed by the Department of Farm Machinery and Power Engineering, PAU, Ludhiana, whereas very little effort has been done regarding planting/transplanting of onions.

Onion can also be grown by direct seeding method which is labour saving. The direct seeding of onion seeds is evolving technology where new techniques of soil preparation, irrigation, fertilizer and pesticide application, seed production and seed processing continue to interact to increase the probability that a well synchronized population of the desired plant density is established. The seed of onion is of very small size, having low density and irregular shape which poses problem in precision planting. To overcome these difficulties 'Seed Pelleting Technique' is being used in the developed countries. In this seed is enclosed in to small quantity of inert material just large enough to produce a globular unit of standard size to facilitate precision planting. In India very little effort has been done for seed pelleting and development of precision planter/drill for sowing the small size, light weight and irregular shaped seeds.

Metering mechanism, the heart of sowing machine distributes seed uniformly at a desired application rate with minimum damage. The commonly recommended metering mechanisms for planters are horizontal plate, inclined plate, vertical rolls with cells etc. [6]. The inclined plate metering system was best suited for metering soaked okra seed [8]. In light of above facts a study was undertaken to develop a metering mechanism i.e inclined plate for mechanical seeding of onion seed.

MATERIAL AND METHODS

Based on the linear dimensions of the onion seeds an inclined plate was developed by adopting design procedure adopted by [2] and [7]. Five design variables shown in (Fig.1) are defined and used to determine the exact size of the groove.

D_g - Depth of the groove. It should be slightly larger than the length of seed.

θ_g - The open angle of groove. It is defined as an angle between the two straight lines connecting the starting and final points of the groove and the centre of the plate, respectively. It determines the loading process of the groove.

β_{rs} - The right side angle of the groove. It determines the ease in loading process of the groove.

β_{ls} - The left side angle of the groove. It determines the seed holding capacity.

R_c - Denotes radius of the curvature of groove bottom. Round groove bottom prevents seeds or other substances from clinging to the bottom.

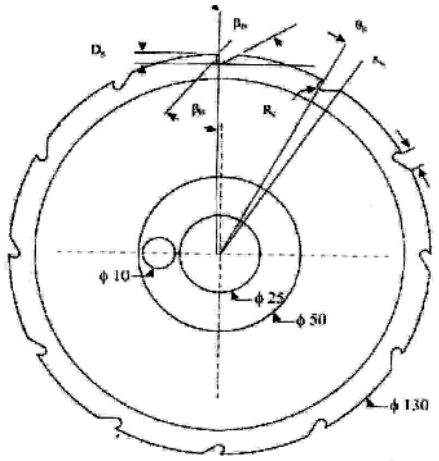

Figure 1. View of plate showing different variables

A brass plate of diameter 130 mm was used to fabricate inclined plate for metering of onion seed. The depth of the groove was selected on the basis of maximum dimensions of the onion seed among the three cultivars studied i.e., Punjab Naroya (PN) Agrifound Light Red (ALR) and Agrifound Dark Red (ADR) which ranged from 2.09 to 3.28 mm. Based on these dimensions; the depth of the groove was selected as 3.5 mm, keeping it 10 per cent more than the maximum major dimension of the seed. The opening of the groove at the periphery of the plate was kept as 5mm, such that two to three seeds are loaded when the groove passes through the seed mass depending upon the orientation of seed. The right angle and the left angle of the groove were selected as 60^o and 40^o such that easy loading of the groove should be done and as well as the seed loaded in the groove should be retained upto the release point (Fig. 2) The different values of the variables are as under: D_g - 3.5 mm, θ_g - 5^o, β_{rs} - 60^o, β_{ls} - 40^o, R_c - 1.5 mm

The bottom of the groove was kept round so that the seeds and foreign matter doesn't clings to the groove. The bottom of the grove had a radius of 1.5 mm. In addition to that, a brush was provided, which was always in contact with the seed plate after the point of release. The brush helps to remove any seed or foreign particle that sticks in the groove, to ensure that the groove is empty when it moves through the seed mass again.

Laboratory evaluation of the prototype. The developed metering mechanisms was evaluated in the laboratory for the missing index, multiple index, average seed spacing, quality of feed index, seed rate, seed damage and degree of variation as per the planned experiment (Tab. 1). The performance parameters were monitored and evaluated according to the procedure described by [4],[8], [9].

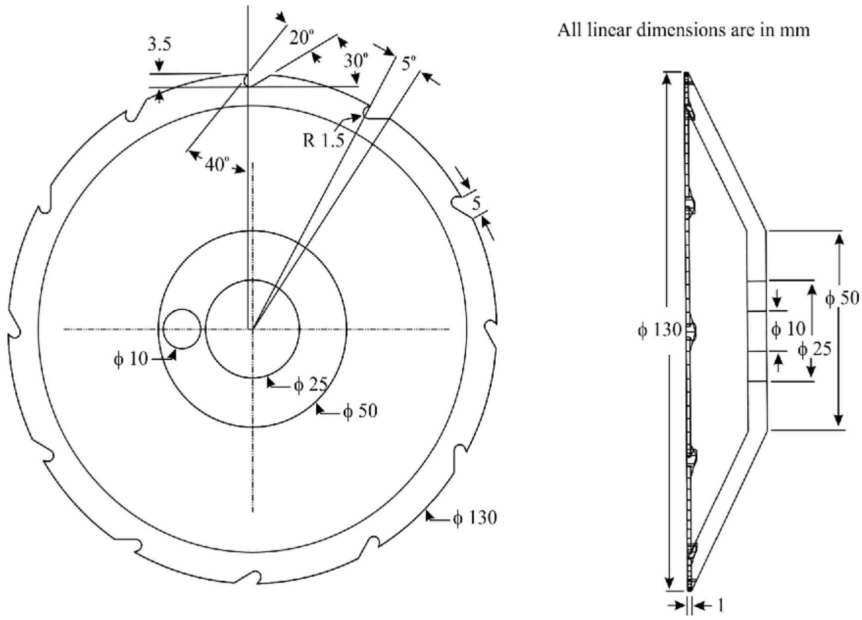

Figure 2. Front and side view of inclined plate

Table 1. Plan of experiment

S. No	*System Variable*	*Levels*	*Values*
1	*Cultivars*	*3*	*Punjab Naroya (PN), Agrifound Light Red (ALR), Agrifound Dark Red (ADR)*
2	*Forward Speed*	*4*	$S_1 – 1.0\ km \cdot h^{-1}$, $S_2 – 1.5\ km \cdot h^{-1}$, $S_3 – 2.0\ km \cdot h^{-1}$, $S_4 – 2.5\ km \cdot h^{-1}$
3	*Angle of inclination of inclined plate with horizontal*	*3*	$A_1 – 47^o$, A_2-55^o, $A_3 – 62^o$

Experimental setup. The set up being used for testing of seed cum fertilizer drills by the Farm Machinery Testing Centre of the department of Farm Machinery and Power Engineering of Punjab Agricultural University, Ludhiana, Punjab was used for laboratory evaluation of the developed prototype. The test rig comprised of moving canvas belt which simulates ground speed of seed drills/planters with provisions to vary the speed of operation and a universal mounting frame to accommodate various seed metering mechanisms. The prototype was fitted on the universal mounting frame and power was given through gear box, variable drive and set of pulleys. Another variable drive having DC motor was used to operate endless belt, which was used to study the seed distribution pattern.

Seed rate. A polythene bag was kept under the furrow opener and the seed was collected for 50 revolutions. Thereafter the seed was weighed and the seed rate was calculated at each speed, seed variety and seed metering mechanism.

Average seed spacing. For the determination of seed spacing, a wooden board of 2 m length and 0.30 m width was used. A white sheet was pinned on the wooden board and thereafter, white grease was placed on the sheet such that the seed dropped on the sheet sticks to it. The grease was used to eliminate the effect of bouncing. The distances between the seeds were measured to compute the average seed spacing.

Missing Index (M). Missing index is an indicator of how often the seed skips the desired spacing. It is the percentage of spacing greater than 1.5 times the theoretical spacing.

$$M = n_1 / N \tag{1}$$

where:
n_1 [-] - number of spacing in the region > 1.5 times of the theoretical spacing,
N [-] - total number of observations.

Multiple Index (D). The multiple index (D) is an indicator of more than one seed dropped within a desired spacing (d). It is the percentage of spacing that are less than or equal to half of the theoretical spacing.

$$D = n_2 / N \tag{2}$$

where:
n_2 [-] - number of spacing in the region d X 0.5 times of the theoretical spacing.

Quality of feed Index (A). The quality of feed index (A) is the measure of how often the spacing was close to the theoretical spacing. It is the percentage of spacing that are more than half but not more than 1.5 times the theoretical spacing. The quality of feed index is mathematically expressed as follows:

$$A = n_3 / N \tag{3}$$

where:
n_3 [-] - number of spacing between 0.5 times the theoretical spacing and 1.5 times of the theoretical spacing.

Degree of variation (c). Degree of variation (c) is a measure of the variability in spacing after accounting for variability due to both multiples and skips. The degree of variation is the coefficient of variation of the spacing that are classified as singles.

$$c = S / X_{ref} \tag{4}$$

where:
S [-] - sample standard deviation of the n_3 observations,
X_{ref} [-] - theoretical spacing.

Seed damage. The seed damage was determined by the germination test in the laboratory. The test was conducted according to International seed testing rules [8]. Three replicates of 100 seeds were placed between two layers of pre-wet germination papers. The set was rolled and placed in upright position by keeping the open plastic bucket in germinator. The germinator was operated at 20°C and 85% relative humidity for 15 days. After fifteen days the number of non germinated seeds was recorded and the seed damage was computed on the basis of germination of the seeds.

RESULTS AND DISCUSSION

Missing index. Missing index is an indicator of the skips in seed metering with in a desired spacing. The missing index was effected by all the parameters studied, i.e. forward speed and angle of inclination of seed metering plate with horizontal for all the three cultivars. The perusal of Fig. 4 reveals that for a particular angle, increase in forward speed resulted in increase of missing index. At an angle of 55°, missing index was observed to be 0.09, 0.16, 0.25 and 0.44 at corresponding forward speeds of 1.0, 1.5, 2.0 and 2.5 km·h^{-1} respectively for cultivar Punjab Naroya. The change in angle also influenced the missing index. Variation in missing index was more pronounced when the angle was changed from 47° to 55°. At every forward speed the missing index increased with increase in angle. Analysis of variance also indicated the significant effect of forward speed and angle of inclination on missing index in all the three cultivars. The increase in missing index with increase in forward speed might be due to decrease in exposure time of cell to seed in the hopper and also the higher centrifugal force at higher speeds may be the reason which throws the seeds from the cell prematurely.

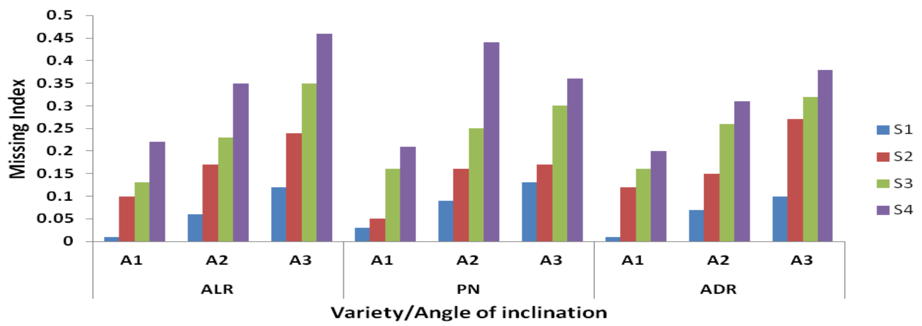

Figure 3. Effect of forward speed and angle of inclination on missing index for the three cultivars of onion

Multiple index. The multiple index is an indicator of more than one seed dropped within a desired spacing. The multiple index decreased with increase in forward speed as well as with increase in angle of inclination of inclined plate with horizontal (Fig. 5). At an angle of 47°, 55°, 62 °, the multiple index decreased from 0.32 to 0.27, 0.29 to 0.15 and 0.26 to 0.10 when forward speed was increased from 1.0 to 2.5 km·h^{-1} for a cultivar ALR. Analysis of variance also indicated that forward speed and angle of inclination of inclined plate with horizontal had significant effect on multiple index

Average seed spacing. The average seed spacing increased with increase in forward speed at all the angles studied for the three cultivars. It was observed that the average seed spacing was approximately close to the theoretical spacing (7.5 cm) at the forward speed of 1.0 and 1.5 km·h^{-1} at an angle of 55^o for all the three cultivars where it deviated at other speeds and angles (Fig. 6). The reason might be the increase in missing and decrease in multiples with the increase in speed. Analysis of variance also indicated that the forward speed had significant effect on average seed spacing. At an angle of 55^o, average seed spacing was observed to be 7.27, 7.50, 7.92 and 10.46 for forward speed of 1.0, 1.5, 2.0 and 2.5 km·h^{-1} respectively for Punjab Naroya.

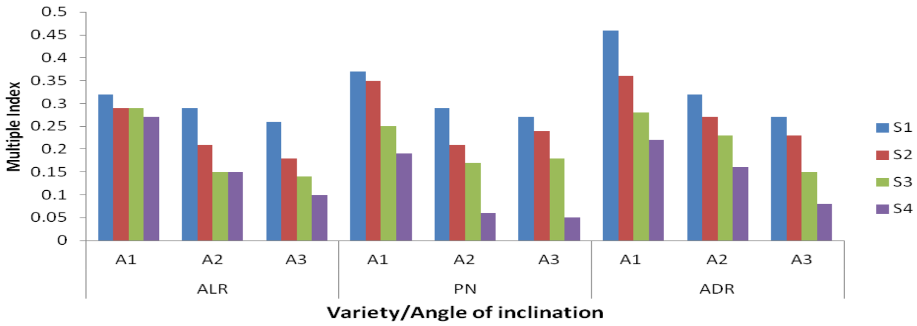

Figure 4. Effect of forward speed and angle of inclination on multiple index for the three cultivars of onion

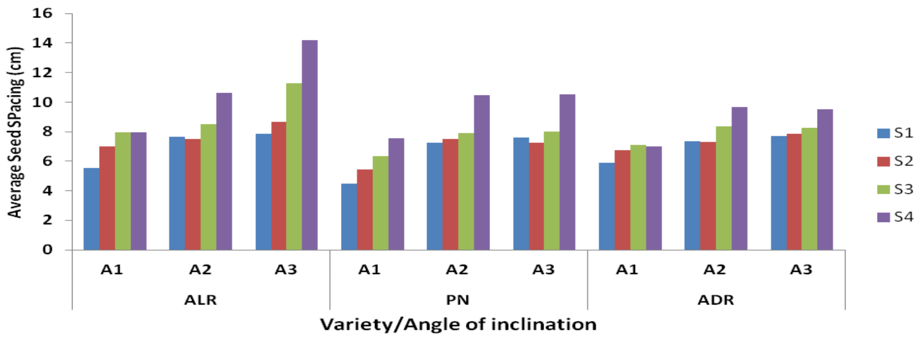

Figure 5. Effect of forward speed and angle of inclination on average seed spacing (cm) for the three cultivars of onion

Quality of feed index. The variation in quality of feed index for PN was observed to be 0.50 to 0.60, 0.44 to 0.67 and 0.51 to 0.63 with the variation in forward speed for PN, ALR and ADR respectively (Tab. 2). The higher values of feed index were observed at slower speed levels, whereas it was lower at higher speed levels. The quality of feed index decreased with increase in speed Analysis of variance also indicated that the forward speed had significant on quality of feed index.

Seed rate. The seed rate decreased with increase in forward speed at all the angles studied for all the three cultivars (Tab. 2). For an angle of 47^o, seed rate was observed to be 3.90, 3.43, 3.08 and 2.98 kg·ha^{-1} at forward speed of 1.0, 1.5, 2.0 and 2.5 km·h^{-1} for PN. Analysis of variance also indicated that the forward speed had significant effect on seed rate. The reduction in seed rate was due to increase in missing index and decrease in multiple index with the increase in forward speed.

Seed damage. The seed damage varied from 1.42 to 3.31 %, 0.75 to 3.02 % and 1.12 to 2.91 % with the variation in speed from 1.0 to 2.5 km·h^{-1} for *PN*, *ALR* and *ADR* respectively (Tab. 2). The minimum seed damage for PN was observed at the speed of 1.5 km·h^{-1} at all the angles studied whereas there was not much variation in seed damage at the speed of 1.0 and 1.5 km·h^{-1} for *ALR* and *ADR*. The change in angle also affected the seed damage which was noted to be lower at an angle of 55^o for all the three cultivars.

Degree of variation. The degree of variation increases with increase in speed at all the angles studied for all the three cultivars (Tab. 2). Analysis of variance also indicated that the forward speed had significant effect on degree of variation. The values of degree of variation varied from 0.14 to 0.33, 0.18 to 0.35 and 0.17 to 0.34 for *PN*, *ALR* and ADR respectively. At an angle of 55^o, the values of degree of variation were observed to be 0.14, 0.19, 0.26 and 0.33 for forward speed of 1.0, 1.5, 2.0 and 2.5 km·h^{-1} respectively for *PN*.

The change in values of degree of variation with the change in angle of inclination of seed metering plate was not significant. Analysis of variance also indicated that change in angle of inclination of seed metering plate from 47° to 62° had non significant effect on degree of variation.

Table 2. Observed values of the performance parameters for the developed metering mechanism

Parameter	Forward speed [km·h^{-1}]	Variety/angle of inclination								
		ALR			PN			ADR		
		A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3
Quality of feed index	S_1	0.67	0.65	0.62	0.60	0.62	0.60	0.53	0.61	0.63
	S_2	0.61	0.62	0.58	0.60	0.63	0.59	0.52	0.58	0.55
	S_3	0.58	0.62	0.51	0.59	0.58	0.52	0.56	0.51	0.53
	S_4	0.51	0.50	0.44	0.60	0.50	0.59	0.58	0.53	0.54
Seed rate [kg·ha^{-1}]	S_1	4.28	3.28	2.90	3.90	3.03	2.68	4.18	3. 73	3.10
	S_2	3.63	2.73	2.40	3.43	2.63	2.43	3.68	3. 58	2.73
	S_3	3.10	2.55	2.18	3.08	2.40	2.23	3.53	3.05	2.60
	S_4	2.78	2.23	2.13	2.98	1.88	2.03	3.08	2.53	2.33
Seed Damage [%]	S_1	0.88	0.75	0.86	2.84	2.37	3.45	1.12	1.12	1.62
	S_2	1.26	0.84	1.60	1.89	1.42	1.75	1.87	1.12	1.50
	S_3	2.70	2.27	2.55	2.36	2.45	1.89	2.62	2.62	2.25
	S_4	3.02	2.52	2.95	3.31	2.51	2.84	2.62	2.91	2.75
Degree of variation	S_1	0.18	0.20	0.25	0.15	0.14	0.16	0.21	0.17	0.24
	S_2	0.26	0.25	0.28	0.18	0.19	0.23	0.25	0.25	0.27
	S_3	0.32	0.32	0.30	0.26	0.26	0.27	0.31	0.28	0.32
	S_4	0.35	0.33	0.35	0.31	0.33	0.32	0.33	0.32	0.34

CONCLUSIONS

The missing index increased, whereas multiple index and seed rate decreased with increase in forward speed for all the varieties and each angle of inclination of the inclined plate with horizontal. Considering all the performance parameters, it was concluded that the forward speed should be in the range of 1 - 1.5 km·h^{-1} and an angle of inclination of seed plate should be 55^{o} with horizontal.

BIBLIOGRAPHY

[1] Anon. 2015. Available through: http://www.dogr.res.in/ (Accessed date: 28.08.2015)

[2] Ahmadi, E., Ghassemzadeh, H.R., Moghaddam, M., Kim, K.U. 2008. Development of precision seed drill for oilseed rape. *Turk J.Agric. For*. 32: 451-458

[3] ISTA. 1999. International rules for seed testing. *Seed Science and Technology* 27 (suppl.): 25 -30

[4] Kachman, S.D., Smith, J.A. 1995. Alternative measures of accuracy in plant spacing for planters using single seed metering. *Transactions of the ASAE.* 38**:**379-387.

[5] Rathnakumari, A.C., Mandhar, S.C., Gowda, R.H. 2003. *Development of drum seeder for onion*. Downsizing Technology for Rural Development. 1**:** 31 – 37

[6] RNAM. 1991. RNAM Test Codes and Procedures for Farm Machinery testing.

[7] Ryu, H.I., Kim, K.U. 1998. Design of roller type metering device for precision planting. *Transactions of the ASAE.* 41: 923-930

[8] Sahoo, P.K., Srivastava, A.P. 2008. Seed pattern characteristics of different metering systems for soaked okra seed. *J. Agric. Engg*.45 **(**1**)**: 1-6.

[9] Singh, H.J., De, D., Sahoo, P.K. 2014. Development and evaluation of metering mechanism for multi crop planter for hilly regions. *Agricultural Engineering.* 4:21-33.

RAZVOJ I OCENA RADA MERNOG MEHANIZMA ZA SETVU SEMENA CRNOG LUKA (*ALLIUM CEPA* L.)

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Sažetak: Crni luk (*Allium cepa* L) je jedna od glavnih povrtarskih kultura u zemlji. Gaji se u različitim delovima zemlje, široko je rasprostranjena, uglavnom kod malih farmera. Generalno, seme crnog luka se seje u rasadnik i presađuje u redove na međurednom rastojanju od 15 cm i rastojanju u redu od 7.5 cm radi dobijanja optimalnog prinosa. Ručni rad u presađivanju klijanaca luka je veoma mnogo zastupljen i iznosi 100 - 120 čovek-dana·ha^{-1} za $8.9 \cdot 10^5$ sadnica po hektaru. Visoki zahtevi mala raspoloživost ručnog rada doveli su do malog prostora na kome se gaju luk, a može se povećati mehanizacijom uzgoja. Zato je razvijena ploča pod nagibom kao merni uređaj za seme luka. Ploča je ispitivana na osnovu vrednosti parametara kao što su: indeks nedostatka, indeks multiplikacije, srednje rastojanje, indeks kvaliteta punjenja, norma setve, oštećenje zrna, stepen varijacije pri četiri radne brzine (1.0, 1.5, 2.0 i 2.5 km·h^{-1}) i tri ugla nagiba (47^o, 55^o i 62^o) merne ploče sa tri sorte luka (Punjab Naroya (PN), Agrifound Light Red (ALR) i Agrifound Dark Red (ADR)). Indeks nedostajanja se povećao, indeks multiplikacije i norma setve su se smanjili sa povećanjem brzine za sve tri sorte i svaki ugao nagiba merne ploče. Uzimajući u obzir sve parametre, zaključeno je da radna brzina treba da bude u opsegu od 1 do 1.5 km·h^{-1}, a ugao nagiba ploče 55^o u odnosu na horizontalnu ravan. .

Ključne reči: *mehanizam za merenje semena, crni luk, ploča pod nagibom, direktna setva, povrće, sadilica, indeks nedostatka, norma setve, rastojanje semena, multipli index*

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SPECTRAL ANALYSIS FOR MONITORING CROP GROWTH USING TRACTOR MOUNTED SPECTRORADIOMETER AND HAND HELD GREENSEEKER IN COTTON

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Abstract: Remotely sensed spectral vegetation indices are widely used and have benefited numerous disciplines interested in the assessment of biomass, water use, plant stress, plant health and crop production. Tractor mounted Spectroradiometer and hand held GreenSeeker were used to capture the spectral signatures of cotton crop canopy and to calculate *NDVI* which indicated the temporal changes in crop canopy, nutritional status and phenological conditions in cotton. The structural mechanism for mounting spectroradiometer on the tractor was prepared with various options of adjustments to use spectroradiometer infield. Spectral signatures of crop were measured using tractor mounted spectroradiometer and GreenSeeker at different growth stages in two cultivars of cotton. The relations between *NDVI* spectroradiometer (R_{650} and R_{770}) and plant N, plant biomass and plant height at p=0.05 level of significance were found as quadratic, exponential and linear with maximum value of coefficient of determination (R^2) of 0.806, 0.807 and 0.801 respectively. However, the relations between NDVI (Green-Seeker) and plant N, plant biomass and plant height at p=0.05 level of significance were found as quadratic, quadratic and linear with maximum R^2 value of 0.828, 0.817 and 0.839 respectively. A close relationship between *NDVI* Spectro-radiometer (R_{650} and R_{770}) and *NDVI* (GreenSeeker) was observed with R^2 value of 0.833 at p=0.05 level of significance. The study suggested that *NDVI* at (R_{650} and R_{770}) using spectroradiometer can be used as a reliable tool for fertilizer N management in cotton.

Keywords: *cotton, spectroradiometer, wavelength, greenseeker, NDVI*

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INTRODUCTION

Cotton (*Gossypium spp.)* a member of Malvaceae family is a major fibre producing crop with high commercial value and global importance. It is grown in temperate and tropical region of more than 70 countries. In terms of botanical status and quality of the fibre, the Indian cotton cultivation is most diverse in the world. All the four cultivated species and their interspecific hybrids are grown only in India. Nitrogen *(N*) is the most important limiting factor in cotton production. Inadequate *N* supply during the vegetative period will slow or stop leaf development. For optimal *N* management, it is important to understand the relationship between the morphological and physiological changes as crop grows. Individual plant species can vary tremendously in physiological behaviour over their life cycle and their nutrient requirements will change during various stages of growth [2].

To optimize the profitability with a reduced environmental impact, the precision agriculture concept was initiated for crop specific management. Precision farming is focused on nitrogen application rate and timing for high yield, crop quality and environmental pollution control [4]. Precision agriculture technology mainly using more information for higher production [6]. Precision agriculture mainly involves ‘the right dose at right place at the right time. The main components of precision agriculture are positioning system, remote sensing, variable rate technology, crop and soil sensing and analysis, yield mapping and information. Hence, agricultural equipments are moving towards the high automation with the help of electronics and information technology.

All objects on the earth produces electromagnetic radiations (*EMR*) is depend upon the physical properties. These are known as ‘spectral signatures’ of particular body Remotely sensed spectral vegetation indices are widely used and have benefited numerous disciplines interested in the assessment of biomass, water use, plant stress, plant health and crop production. Hyperspectral remote sensing capability to detect characteristic differences of cotton canopy under different nitrogen application rates and different growing stage was studied [7]. Hyper spectral reflectance from cotton crop canopy was used to find indices like Difference Vegetation Index (*DVI*), Ratio Vegetation Index (*RVI*), Normalized Difference Vegetation Index (*NDVI*), and Renormalized Difference Vegetation Index (*RDVI*) [8].

Spectroradiometer captures the reflectance of cotton crop canopy at different wavelength and helps in finding the vegetative indices *DVI*, *RVI*, *NDVI* and *RDVI* relations with plant *N*, plant height, above ground biomass at various growth stages of crop. It would help growers make field management decisions such as fertilizer application, irrigation scheduling, and plant growth regulator applications for maximum yield and quality.

Now days, hand held portable spectroradiometers are being used to collect the hyperspectral data of cotton crop canopy. Manually operated spectroradiometer having problem of non-uniform height, shaking of hand and spectral probe is not uniformly perpendicular to crop canopy. These problems cause the disturbed spectral data. To avoid these problems there is a requirement of development structural mechanism for mounting a spectoradiometer on tractor.

The present study has been planned with the following objectives:

1. To develop structural mechanism for mounting of spectroradiometer on the tractor to capture hyper spectral data of cotton crop canopy.

2. To develop relationships between *NDVI* calculated using tractor mounted Specctroradiometer and hand held GreenSeeker with different growth parameters.
3. To study relationship between *NDVI* calculated by using Spectroradiometer and GrenSeeker.

MATERIAL AND METHODS

The field experiment was conducted during crop season *kharif* 2014 at the experimental farm, Department of Soil Sciences, Punjab Agricultural University, Ludhiana, Punjab, India at 30°56' N latitude and 75°52' E longitude with a mean height of 247 meter above the mean sea level. The field experiment was designed in split plot design with two cultivars (*ANKUR* 3028 *BG*- II and *RCH* 650) in main plots and seven N fertilizer applications (0, 30, 60, 75, 90, 120 and 150 kgN·ha^{-1}] treatments in sub plots with three replications. Total 42 plots of size 9 x 2.7 (24.3 m^2) were sown at row to row spacing of 60 cm and plant to plant spacing of 67.5 cm.

Development and fabrication of frame to mount spectoradiometer on tractor. The computer aided design of structural mechanism for mounting spectroradiometer on the tractor was prepared in three – dimensional solid modeling software tool called *CATIA* .The frame was fabricated using 60 × 60 mm iron square hollow bar, iron plate, iron rod as dimension given in (Fig. 1). The fabricated frame having various options of adjustments to use spectroradiometer infield during various crop growth stages was mounted on the high clearance tractor (Fig. 2).

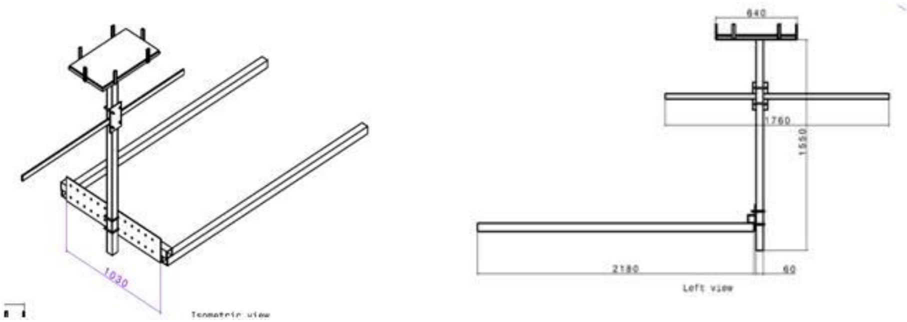

Figure 1. Structural mechanism for mounting spectroradiometer on the tractor (all dimension in mm)

Collection of Spectral Signatures. Spectral properties of cotton crop were measured using tractor mounted Specroradiometer and handheld GreenSeeker at 10 days interval starting from squaring stage of 41 days after sowing (*DAS*) to boll opening stage of 101 *DAS*.

Tractor Mounted Spectroradiometer. A 512 – channel *ASD* Fieldspec® Pro 2000 Specroradiometer (Analytical Spectral Device Inc., Boulder, CO, USA) with range 350 – 2500 nm was mounted on developed frame mounted on high clearance tractor *(Figure. 2).* A Spectralon white reference panel was used to optimize the instrument to 100 %

reflectance at all wavebands prior to canopy reflectance measurement. Canopy spectra from cotton were measured at 11:00 – 14:00 hours under cloudless and windless weather conditions. Reflectance measurement was made about 1 m above canopy throughout the growing season. Sensor facing the crop and oriented normal to plant using 25° field of view (*FOV*) was used to get 5 spectral reflectance measurements from each plot. During the reflectance measurement tractor was kept in steady state.

Figure 2. Capturing of spectral signatures of cotton crop using tractor mounted specroradiometer and hand held GreenSeeker

GreenSeeker optical sensor. The GreenSeekerTM hand held optical sensor unit Model 505 was used to measure NDVI from the crop canopy using light emitting diodes with reflectance in red region (656 nm) and *NIR* (774 nm). Before taking the readings, iPAQ was inserted in the powered cradle and battery was charged properly. Then shoulder strap was put around the body andsensor angle was such adjusted that it was kept parallel to sensing area at a height of about 1.0 m above the canopy (Fig. 2). The trigger of GreenSeeker optical sensor was pressed continuously while moving in the middle of the crop rows and trigger was released after completing one plot. A photo diode detector within the sensor measured the magnitude of the light reflected off the target and *NDVI* was computed. The data from the sensor was transmitted serially to HPiPAQ Personal Digital Assistant, which was later exported to a desktop computer for analysis.

Collection of samples and analysis. One cotton plant was collected at different growth stages. The samples were oven dried at 60°C to record the dry weight of leaves and plant biomass. Dried samples were grounded in grinder for estimating N content. The stover samples were collected at harvesting and were also dried at 60°C for N content analysis. Nitrogen concentration in the leaf, plant and stover were determined by Kjeldhal method [1].

Selection of wavelength for NDVI from tractor mounted spectroradiometer. Spectroradiometer was used to measure the reflectance of five randomly selected plants in each plot during various growth stages of cotton crop. Average reflectance of five plants recorded at each wavelength from 350 nm to 2500 nm. Normalized Difference Vegetative Index (*NDVI*) was selected as indicator of total biomass and greenness of leaves and determined with the following equation:

$$NDVI = (NIRref - REDref) / (NIRref + REDref) \qquad (1)$$

where:
NIR ref [-] - reflectance in the near infrared region,
RED ref [-] - reflectance of in the red region.

From that average value of reflectance *NDVI* was calculated for four selected combinations of wavelengths using one wavelength in *NIR* (770 nm) which is sensitive to *N* application (Broson*et al* 2005) with three selected wavelengths in red region (600 nm, 650 nm and 700 nm). However fourth *NDVI* was calculated by using average reflectance of wavelength in *NIR* region (749 nm-950 nm) and red region (620-650 nm).

Statistical Analysis. An analysis of variance (*ANOVA*) was performed to test N effects on plant N, plant biomass, plant height, *NDVI* (R_{600} and R_{770}), *NDVI* (R_{650} and R_{770}), *NDVI* (R_{700} and R_{770}) *NDVI* (R_{red} and R_{NIR}) and *NDVI* (GreenSeeker). Mean separation was determined using LSD at level of significance of $P = 0.05$. Analyses were performed using software Crop stat. *NDVI* (R_{600} and R_{770}), *NDVI* (R_{650} and R_{770}), *NDVI* (R_{700} and R_{770}) and *NDVI* (R_{red} and R_{NIR}) was related to plant N, plant biomass and plant height. The software used for all curve fittings was TableCurve^{TM} 2D windows version 4.06 (SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

Relations between plant height, plant N, plant biomass and *NDVI* using tractor mounted spectroradiometer and hand held GreenSeeker

The reflectance around 550 or 585 nm in green region was closely correlated with cotton leaf N content [5]. *NDVI* calculated from reflectance at 2 m above the cotton canopy was positively correlated with biomass and lint yield [3]. The relation between *NDVI* (Spectroradiomer) and plant height, plant *N*, plant biomass and at p=0.05 level of significance was linear, quadratic and exponential with maximum R^2 value of 0.801, 0.807 and 0.807 respectively (Tab. 1, Fig.. 3). The relation between *NDVI* (GreenSeeker) plant height, plant *N* and plant biomass at p=0.05 level of significance was linear, quadratic and quadratic with maximum R^2 value of 0.839, 0.817 and 0.817 respectively (Tab. 2, Fig. 4).

Table 1. Relation between plant N, plant biomass, plant height and NDVI (Spectroradiometer)

Parameter	*Relation*	*Equation*	R^2
Plant height	*Linear*	$y = 293.41x – 137.22$	*0.801*
Plant N	*Quadratic*	$y = 39.757x2 + 52.229x – 14.356$	*0.806*
Plant biomass	*Exponential*	$y = 0.0031e^{13.499x}$	*0.807*

Table 2. Relation between plant N, plant biomass, plant height and NDVI (GreenSeeker)

Parameter	*Relation*	*Equation*	R^2
Plant height	*Linear*	$y = 175.33x – 36.076$	*0.839*
Plant N	*Quadratic*	$y = -11.129x^2 – 10.969x + 0.0758$	*0.828*
Plant biomass	*Quadratic*	$y = 1249.8x^2 – 913.91x + 160.09$	*0.817*

Relation between *NDVI* calculated using tractor mounted spectroradiometer and hand held GreenSeeker

Overall relations of *NDVI* (GreenSeeker) with *NDVI* (R_{600} and R_{770}), *NDVI* (R_{650} and R_{770}), *NDVI* (R_{700} and R_{770}), NDVI (R_{Red} and R_{NIR}) across the cultivars at different growth stages were established (Figs. 5 to 8).

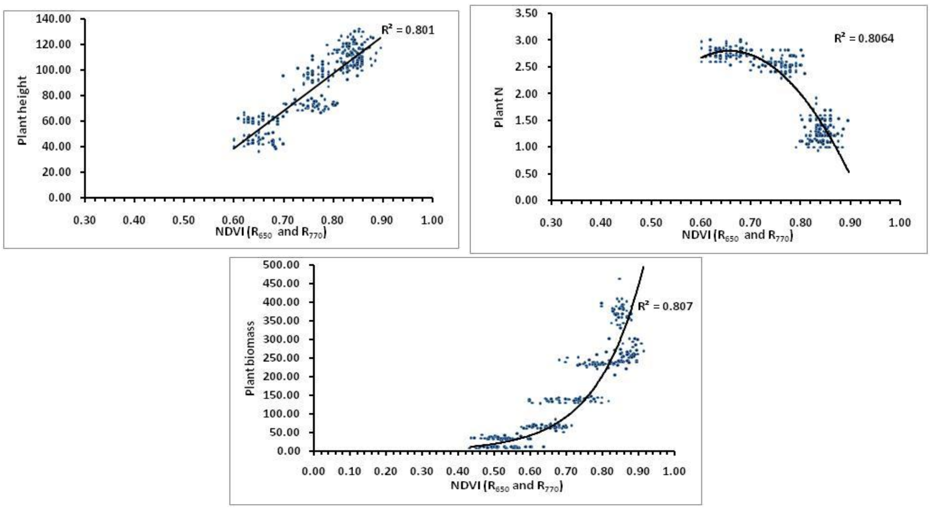

Figure 3. Relation between plant height, plant N, plant biomass and NDVI (R_{650} and R_{770}) calculated using tractor mounted Spectroradiometer

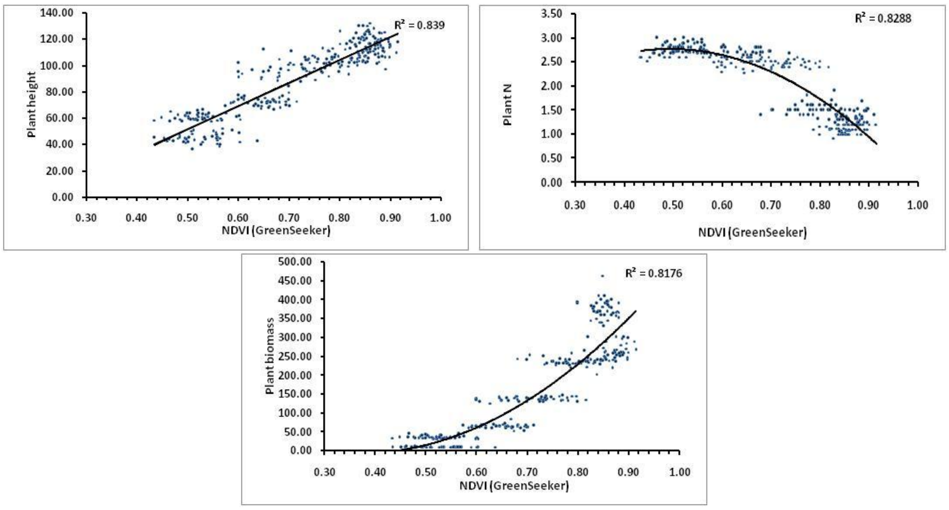

Figure 4. Relation between plant N, plant biomass, plant height and NDVI calculated using hand held GreenSeeker

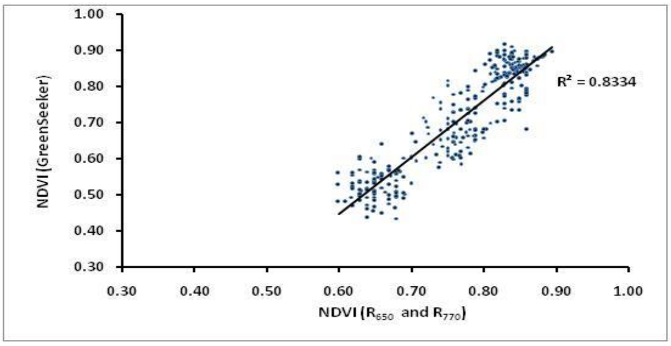

Figure 5. NDVI (R_{600} and R_{770}) calculated using tractor mounted spectroradiometer and NDVI calculated using hand held GreenSeeker

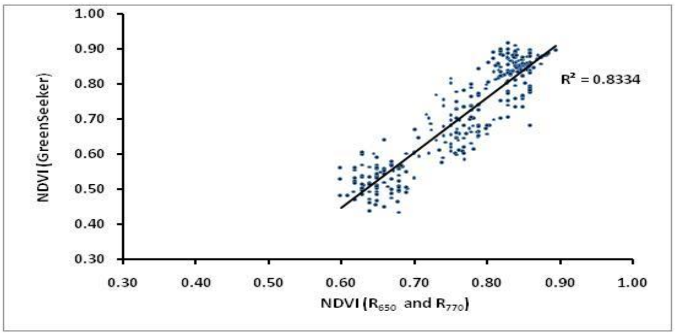

Figure 6. NDVI (R_{650} and R_{770}) calculated using tractor mounted spectroradiometer and NDVI calculated using hand held GreenSeeker

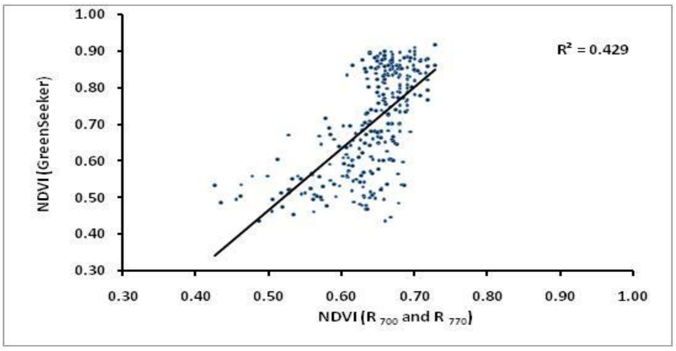

Figure 7. NDVI (R_{700} and R_{770}) calculated using tractor mounted spectroradiometer and NDVI calculated using GreenSeeker

A close relationship between *NDVI* (GreenSeeker) and *NDVI* Spectroradiometer (R_{650} and R_{770}) was observed with coefficient of determination (R^2) of 0.833 at p=0.05 level of significance at different growth stage of cotton (Fig. 6). However, *NDVI* (GreenSeeker) and *NDVI* Spectroradiometer (R_{600} and R_{770}), *NDVI* (R_{700} and R_{770}), *NDVI*

(R_{Red} and R_{NIR}) at p=0.05 level of significance at different growth stage of cotton were not closely related (Fig. 5, 7 and 8). The data suggested that *NDVI* (R_{650} and R_{770}) can be used as a reliable substitute of *NDVI* (GreenSeeker) to guide in season fertilizer N topdressings in cotton.

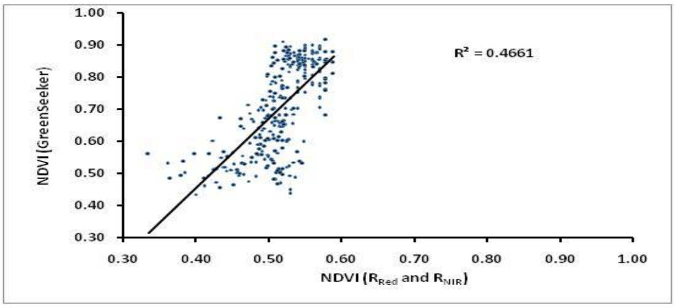

Figure 8. NDVI (R_{Red} and R_{NIR}) calculated using tactor mounted spectroradiometer and NDVI calculated using GreenSeeker

CONCLUSIONS

Structural frame was developed for mounting specroradiometer on tractor for capturing the spectral signatures of cotton crop canopy with uniform height of 1m above the crop canopy.

- *NDVI* calculated using reflectance in red region at 650nm and reflectance in *NIR* region at 770 nm had quadratic, exponential and linear relation with plant N content, plant biomass and plant height respectively.
- *NDVI* calculated using hand held GreenSeeker had linear, quadratic and quadratic relation with plant height, plant biomass and plant N.
- Linear relation was observed between *NDVI* calculated using reflectance in red region at 650nm and in NIR region at 770 nm by spectroradiometer and NDVI (GreenSeeker).
- It was found that *NDVI* at (R_{650} and R_{770}) using spectroradiometer can be used as a reliable tool for fertilizer N management in cotton.

BIBLIOGRAPHY

[1] Bremner, J.M., Mulvaney, C.S. 1982. *Total nitrogen*. In: Page A.L, Miller R H., Keeney D.R. (eds) Methods of soil analysis: Part 2. Chemical and microbiological properties. pp 595-624.

[2] Jeffery, C.S., Broson, F.K., Norton, E.R., Mikkelsen, R. 2011. Nitrogen Utilization by Western U.S. Cotton. *Better Crops* (95), 21-23.

[3] Li, H., Lascano, R.J., Barnes, E.M., Booker, J., Wilson, L.T., Bronson, K.F., Segarra, E. 2001. Multispectral Reflectance of Cotton Related to Plant Growth, Soil Water and Texture, and Site Elevation. *Agronomy Journal* (93),1327-37.

[4] Pattey, E., Strachan, I.B., Boisvert, J.B., Desjardins, R.L., McLaughlin, N. 2001. Effects of Nitrogen Application Rate and Weather on Corn using Micrometeorological and Hyperspectral Reflectance Measurements. *Agriculture and Forest Meteorology* (108), 85– 99

[5] Read, J.L., Tarpley, J.M., McKinion, Reddy, K.R. 2002. Narrow-Waveband Reflectance Ratios for Remote Estimation of Nitrogen Status in Cotton. *Journal of Environmental Quality* (3I), 1442-52.

[6] Schneider, M., Wanger, P. 2007. Prerequisites For The Adoption Of New Technologies – The Example Of Precision Agriculture. *Scientific Journal Agricultural Engineering* (XXXII), 9-14.

[7] Zhao, D., Jianlong, L.I., Jiagua, Q.I. 2004. Hyperspectral Characteristic Analysis of a Developing Cotton Canopy under Different Nitrogen Treatments. *Journal of Agronomy* (24), 463-71.

[8] Zhao, D., Reddy, R.K, KakaniGopal, V., Reddy, V.R. 2005. Nitrogen Deficiency Effects on Plant Growth, Leaf Photosynthesis and Hyperspectral Reflectance Properties of Sorghum. *European Journal of Agronomy* (22), 391-403.

SPEKTRALNA ANALIZA ZA PRAĆENJE PORASTA USEVA POMOĆU TRAKTORSKOG SPEKTRORADIOMETRA I RUČNOG SENZORA STANJA USEVA U PAMUKU

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Sažetak: Daljinska spektralna detekcija vegetacije se široko koristi u mnogim oblastima u kojima je potrebna procena biomase, korišćenja vode, stresa kod biljaka, zdravlja biljaka i biljne proizvodnje. Traktorski spektroradiometar i ručni sensor stanja useva su korišćeni za snimanje spektralnih potpisa useva pamuka i proračun *NDVI* indeksa, što je pokazalo povremene promene biljnog pokrivača, nutritivno stanje i fenološke uslove u kojima se pamuk nalazi. Konstrukcija za postavljanje pektroradiometra na traktor je izvedena sa različitim mogućnostima za podešavanje upotrebe uređaja na parceli. Spektralni potpisi useva mereni su spektroradiometrom postavljenim na traktoru i ručnim senzorom stanja useva u različitim fazama porasta kod dve sorte pamuka. Odnsoi između *NDVI* indeksa spektroradiometra (R_{650} i R_{770}) i biljnog azota, biomase biljaka i visine biljaka na nivou značajnosti p=0.05 bili su kvadratni, eksponencijalni i linearni, sa maksimalnim vrednostima koeficijenta determinacije (R^2) od 0.806, 0.807 i 0.801, redom. Pored ovoga, odnosi između *NDVI* (Green-Seeker) i biljnog azota, biomase biljaka i visine biljaka na nivou značajnosti p=0.05 bili su kvadratni, kvadratni i linearni, sa maksimalnom vredošću R^2 od 0.828, 0.817 i 0.839, redom. Značajna zavisnost *NDVI* spektroradiometra (R_{650} i R_{770}) i *NDVI* (GreenSeeker) bila je utvrđena sa vrednošću R^2 od 0.833 na nivou značajnosti p=0.05. Istraživanje je pokazalo da *NDVI* kod (R_{650} i R_{770}) upotrebom spektroradiometra može da se upotrebi kao pouzdano sredstvo za upravljanje đubrenjem azotom kod pamuka.

Ključne reči: *pamuk, spektroradiometar, talasna dužina, ručni senzor stanja useva, NDVI indeks*

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COMPARATIVE FIELD EVALUATION OF DIFFERENT MECHANIZED PLANTING TECHNIQUES IN NAPIER-BAJRA

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Abstract: The 17th Livestock Census (2003) has placed the total livestock population at 485 million and that of poultry birds at 489 million. Total population is expected to grow 1.23% in the coming years. At present, the country faces a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% feeds. Overlapping cropping systems have been developed at the Indian Grassland and Fodder Research Institute (IGFRI), Jhansi, to fulfill the needs of dairy farmers for green fodder throughout the year. Napier-Bajra is perennial and once planted it gives fodder for 2-3 years. The sowing practices/machine has a significant effect on green fodder yield of fodder crops. Therefore, present study was conducted to evaluate the performance of three planters namely Semi-automatic type, sugarcane cutter planter, vegetable nursery planter and potato planter for sowing of Napier- Bajra variety PBN-233. The number of plants/ha for sugarcane cutter planter, vegetable transplanter, potato planter and control were 23,563, 19,895, 21,442 and 20,826 respectively. Green fodder yield was highest for sugarcane cutter planter as 279.13 $t \cdot ha^{-1}$ and for semi-automatic potato planter, vegetable nursery transplanter and control were 262.79, 250.42 and 255.25 $t \cdot ha^{-1}$ respectively. Benefit cost ratio for sugarcane cutter planter, vegetable nursery transplanter, potato planter and control were 2.49:1, 2.17:1, 2.38:1 and 2.27:1 respectively. The saving in time with semi-automatic potato planter, vegetable nursery planter and sugarcane cutter planter as compared with manual sowing method were 77.78 %, 33.33 %, and 75.00 % respectively.

Key words: *Napier-Bajra hybrid, sugarcane cutter planter, field capacity, yields.*

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INTRODUCTION

Fodder crops are the plant species that are cultivated and harvested for feeding the animals in the form of forage (cut green and fed fresh), silage (preserved under anaerobic condition) and hay (dehydrated green fodder). The total area under cultivated fodders in India is 8.3 million ha on individual crop basis. Sorghum amongst the *kharif* crops (2.6 million ha) and berseem (Egyptian clover) amongst the *rabi* crops (1.9 million ha) occupy about 54% of the total cultivated fodder cropped area. The area under permanent pastures has been declining over the years and the trend could well continue in the future. Due to overgrazing, the productivity of the pastures has been declining too. The area under fodder crops has almost remained static for the last 3-4 decades [1]. The area under fodder crops in the Punjab state is approximately 0.86 million hectares (3.45 lac hectares in rabi season) and the annual production is about 67.27 million tonnes of green fodder. At present fodder supply of 30.5 kg/animal/day is far from satisfactory. On the basis of 40 kg green fodder per adult animal per day approximately 88.2 million tons of fodder will be required. [2]. Napier-Bajra hybrid is a vegetatively propagated bajra like grass. It is perennial but yields most of the fodder between March and November. Sowing of perennial grass and forage legume components helps reduce the necessity of repeated sowing and tillage and to economize the use of irrigation water in the system.
During 1989 and 2000, various forage breeding institutions in the world have developed vast number of Bajra x Napier hybrids. Scientists of the Southern African Development Community (SADC), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Sorghum and Millet Improvement Programme (SMIP) in Zimbabwe and Punjab Agricultural University (PAU) and Tamil Nadu Agricultural University (TNAU) in India were the pioneers of this effort [6].

A study was conducted to evaluate the effect of use of tractor operated seed- cum fertilizer drill for its field performance in comparison with bullock drawn seed drill (*Tifan*) for sowing sorghum crop (CSH-9) as per RNAM test codes. The field test was conducted on medium black soil at moisture content of 33.60%. It was found that tractor operated seed-cum-fertilizer drill works better than bullock drawn seed drill in respect of effective field capacity, field efficiency, depth of placement of seed, yield of crop, yield of fodder and cost of sowing per hectare. The mechanized method of sowing has resulted in a 66.70% increase in effective field capacity, 22.36% increase in field efficiency, 20.00% increase in depth of seeding, 16.76% increase in grain yield, 19.14% increase in fodder yield, 66.40% saving in operation of time and 44.70% saving in cost of operation. The overall benefit of Rs.412.12/- per hectare was observed by using mechanized method of sowing [3].

Napier-Bajra is perennial and once planted it gives fodder for 2-3 years. It can be planted from the last week of February to May. The planting should be completed by mid April to avoid mortality of root slips. The crop planted after May does not give sufficient yield during Kharif season. Fourteen hybrids of Bajra Napier genotypes were analyzed for water soluble oxalate content and yield at 40th and 80th day of harvestings. Oxalate content decreased with delayed harvest (80th Day) compared to early harvest (40th day); however, it ranged between 2 – 3 % in all the hybrid genotypes which is under permissible tolerance limits. APBN-1 and PBN-91 are emerging as the promising genotypes with respect to oxalate and biomass production than the standard checks at 40th day of harvest [4]. A comprehensive examination was done to analyse the machine fleet formation and machine use of plant production farms that grow sweet sorghum too by using computer aided modeling. It considers the characteristics of machines used at the production technologies of different plants and it especially focuses on the appliance of machines with the convenient capacity and level from the side of costs at different farm sizes. The total production cost of sweet sorghum per hectare in case of small-scale farm size is minimum 715 EUR. Examining the large-scale production the costs reduce, but they cannot be reduced under the 610 EUR/hectare levels [5].

Timely sowing of Napier Bajra is very important to avoid reduction in fodder yield. Mechanized sowing of this crop is only solution to avoid delay in sowing and reduction in its yield and save labor cost involved in sowing operation. Therefore, present study was conducted to see the response of Napier-Bajra hybrid crop (PBN-233) to three different planters' namely semi-automatic potato planter, vegetable nursery transplanter and sugarcane cutter planter.

MATERIAL AND METHODS

The farm yard manure was applied in the field prior to cultivation and the land was well prepared and made free from weeds. The first ploughing with a disc harrow and subsequent two ploughings with a cultivator were given to field. Napier-Bajra can be propagated vegetatively from root slips or stem cuttings. In the present study stem cuttings (with two nodes) were used for planting. Approximately 27,500 slips or cuttings are required to plant one hectare. The stem cuttings were planted like sugarcane sets in furrows which were afterwards filled with soil. The crop was planted at 60 x 60 cm spacing under good conditions of soil moisture. Tractor operated three row semi-automatic revolving magazine type potato planter, two row semi-automatic revolving magazine type vegetable transplanter and two row semi-automatic sugarcane cutter planter were used for sowing of Napier-Bajra hybrid, PBN-233 at Departmental fodder research farm. For control, manual sowing of Napier-Bajra was also done. The Napier-Bajra crop was planted with these three planters and by control method and germination data was recorded after 40 days. The observations recorded were forward speed, fuel consumption, depth of set placement. Number of plants/ha, plant to plant spacing was recorded for all the Napier-Bajra plots sown by three planters. The first cutting was done after 50 days of planting and subsequent five cuttings were done when the crop was about one meter high. The green fodder yield was recorded for Napier-Bajra crop sown with three different planters and by control method also. The detail of three planters studied for planting of Napier-Bajra hybrid crop is given below.

1. A three row semi-automatic revolving magazine type potato planter. A three row semi-automatic revolving magazine type potato planter was used for sowing of Napier-Bajra sets (Fig. 1). It consisted of four furrow openers, seed tubes, rotating plates named as magazines, seed hopper, ground wheel and four ridger bottoms and three seats for the labourers to fill magazines. Seed metering mechanism for metering the Napier-Bajra sets was operated by a ground wheel. The power from ground wheels was transmitted to the three rotating magazines through chain and sprockets. With the rotation of ground wheels, a hub having three sprockets (10, 15 and 20 teeth) on ground wheel shaft axle was rotated by ground wheel and power was transmitted to sprocket (having 30 teeth) of main shaft through chain. Horizontal shaft transmitted power to vertical shaft with the help of bevel gear assembly (1:1). As the vertical shaft was rotated, the revolving magazine metering mechanisms were rotated. The front view of this machine is shown in Fig. 2. Machine was operated by 45 HP tractor. The plant spacing can be varied with the help of adjustable ground wheel. Three persons were required to feed the Napier-Bajra sets to the feeding mechanism. This machine consisted of four ridgers mounted on the frame for opening the furrows. As the Napier-Bajra sets were sown in these furrows by planting mechanism, ridgers covered them with soil and in this way it makes three beds. The drive to feeding mechanism was provided through a ground wheel.

Figure 1. View of Napier-Bajra sowing and potato planter machine

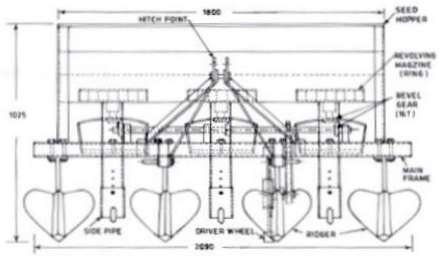

Figure 2. Front view of semi-automatic potato planter (all dimensions in mm)

2. A two row vegetable nursery transplanter with revolving magazine type. A two row vegetable transplanter with revolving magazine type metering mechanism was used for sowing of Napier-Bajra crop (Fig. 3).

Figure 3. View of Napier-Bajra sowing with two row semi-automatic vegetable nursery transplanter

A wooden board having length 169 cm and width 32 cm was attached to the four angles and that were attached to the main frame with U clamps. A support was attached to the seat. Two revolving magazine type metering mechanism were developed. It consisted of two curved runners with their cutting edges on the ground and meeting at a point. At the rear, runners were connected to common boot through which the seedling was dropped. The length of the furrow opener was 535 mm and height 230 mm. It was made of high carbon sheet having thickness of 6.0 mm. The furrow width made by furrow opener was 100 mm. The four packing wheels made of mild steel sheet of thickness of 3 mm were used to press soil along the Napier-Bajra sets. With the rotation of ground wheels, a hub having three sprockets (10, 15 and 20 teeth) on ground wheel shaft axle was rotated by ground wheel and power was transmitted to sprocket (having 30 teeth) of main shaft through chain. Horizontal shaft transmitted power to vertical shaft with the help of bevel gear assembly (1:1).As the vertical shaft was rotated, the revolving magazine metering mechanisms were rotated. The sets of bajra were sown by these magazines. The side view of this machine is shown in Fig. 4.

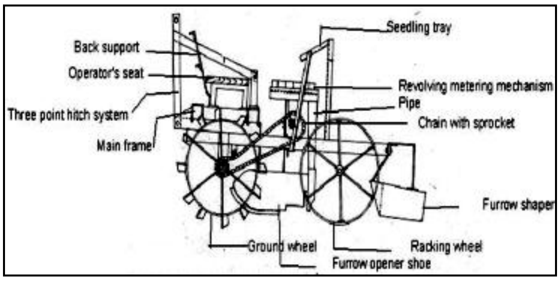

Figure 4. Side view of vegetable nursery transplanter

3. A two row ridger type semi-automatic sugarcane cutter planter. A two row ridger type semi-automatic sugarcane cutter planter operated by tractor PTO was used for sowing of Napier-Bajra. Two persons were required to feed the Napier-Bajra to the cutting mechanism. It consists of two ridgers mounted on the frame for opening the furrows. The spacing between ridgers can be adjusted from 600-900 mm. This machine has two set cutting units i.e. one for each row. Each set cutting unit consists of two blades mounted on separate shafts rotating in opposite directions. Also, 5 rubber rollers are mounted on each shaft. The rubber rollers hold the fed Napier-Bajra and blades cut it into desired size. The cut pieces are then dropped in the furrows. The distance between two Napier-Bajra sets in furrow depends upon the forward speed of tractor. A fertilizer hopper of about 50 kg capacity with a agitator is mounted beneath the seats. It has two holes at the base to drop the granular fertilizer by gravity. For varying the fertilizer application rate, hole is changed with the help of a lever.

Figure 5. View of sugarcane cutter planter with set covering unit raised

Figure 6. View of sugarcane cutter planter with covering unit lowered

It has two tanks of capacity 35 liters each for chemical application. The solution was sprinkled on the set through the nozzles. The flow rate of solution is adjusted by control lever. A set covering unit is provided to cover sets after planting. It consists of a furrower in the centre of two units and a shovel with half mould board plate behind each row for covering the set with soil and a flat for pressing the soil lightly over the set. The planter has two hoppers for two rows to store sufficient quantity of whole bajra feeding. Power is transmitted through tractor PTO to the machine through telescopic shaft to operate set cutting mechanism and fertilizer and chemical unit. The view of this machine while sowing Napier-Bajra without placing down the set covering unit is shown in Fig. 5 and its view with set covering unit down is shown in Fig. 6.

The specifications of these three planters and various field operational parameters are shown in Tab. 1.

Table 1. Specifications and operational parameter of different planters

Particulars	*Semi-automatic potato planter*	*Semi-automatic vegetable nursery transplanter*	*Semi-automatic sugarcane cutter planter*	*Control (Manual sowing method)*
Tractor HP required	*45 HP*	*35 HP*	*45 HP*	---
Number of rows	*3*	*2*	*2*	---
Ground wheel diameter/driving Pulley diameter, mm	*390*	*595*	*140*	---
Feeding mechanism	*revolving magazine type*	*revolving magazine type*	*rubber rollers with blades*	---
Revolving magazine/roller diameter (number of holes/rollers)	*370 mm (9 holes)*	*370 mm (9 holes)*	*130 mm (5 rollers of 40 mm dia each)*	---
Forward speed, $km \cdot h^{-1}$	*1.50*	*1.00*	*1.55*	---
Field capacity, $ha \cdot h^{-1}$	*0.18*	*0.06*	*0.16*	*0.04*
Mean Fuel Consumption, $l.h$-^{1}	*6.00*	*5.50*	*6.00*	---
Overall Speed ratio	*1:1*	*2:1*	*3.7 : 1*	---
No. of labour required	*5*	*4*	*4*	*10*
Labour requirement man-$h.ha^{-1}$	*33*	*72*	*30*	*250*
No. of nodes on each set	*2*	*2*	*2*	*2*
Depth of set placement, mm	*100-150*	*25-60*	*120-155*	*25-35*
No. of stem cuttings per ha	*27,500*	*27,500*	*30,250*	*27,500*
% age eye damage	--	--	*7.25 %*	---

RESULTS AND DISCUSSION

The Napier-Bajra crop was planted with these three planters and germination data was recorded after 40 days and view of crop is shown in Fig. 7. Number of plants/ha, plant to plant spacing was recorded for all the Napier-Bajra plots sown by three planters and control method. The first cutting was done after 50 days of planting and subsequent five cuttings were done when the Napier-Bajra reached to one meter height. The green fodder yield was recorded for Napier-Bajra crop sown with three different planters and control method. All these recorded parameters are shown in Tab. 2. The crop view is shown in Fig. 7.

Figure 7. View of Napier-Bajra hybrid crop (50 days after DOP) sown by different planters

Table 2. Field data of Napier-Bajra hybrid crop (PBN-233) sown with different planters

Machine/Technique used for sowing	*Napier Bajra sets used*	*No. of plants/ha*	*Mean plant to plant spacing (mm)*	*Mean green fodder yield ($t\cdot ha^{-1}$)*
Semi-automatic potato planter	*sets with two nodes*	*21,442*	*725.00*	*262.79*
Semi-automatic Vegetable nursery transplanter	*sets with two nodes*	*19,895*	*756.73*	*250.42*
Semi-automatic Sugarcane cutter planter	*full length plant*	*23,563*	*668.37*	*279.13*
Control (Manual Sowing method)	*sets with two nodes*	*20,826*	*742.15*	*255.25*
CD (5 %)	-------	*33.6888*	*7.06222*	*2.58948*

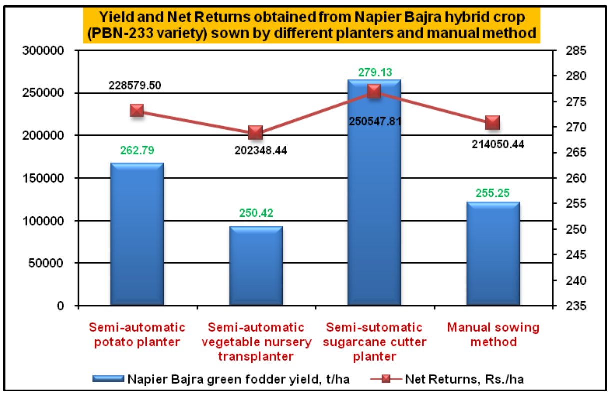

Figure 8. Effect of three different planters and manual sowing method on yield and net returns from Napier- Bajra hybrid crop

Table 3. Economics of different planters for sowing of Napier-Bajra hybrid crop (PBN-233 var.)

Particulars	*Semi-automatic potato planter*	*Semi-automatic Vegetable nursery transplanter*	*Semi-automatic sugarcane cutter planter*	*Control (manual sowing method)*
Field capacity, ha.h^{-1}	*0.18*	*0.06*	*0.16*	*0.04*
Farm yard manure and application cost, Rs.ha^{-1} [50t/ha@Rs.1333.33per tone + labour cost@166.67 per tonne]	*75000.00*	*75000.00*	*75000.00*	*75000.00*
Land Preparation Cost, Rs.ha^{-1} [Disc harrow(2) + cultivator(2) + planker (1)]	*6116.75*	*6116.75*	*6116.75*	*6116.75*
Sets/seed cost, Rs.ha^{-1}	*27,500.00*	*27,500.00*	*30,250*	*27500.00*
Set cutting labour cost, Rs.ha^{-1}	*312.50*	*312.50*	*----*	*312.50*
Operational cost, Rs.ha^{-1} (Fixed and variable)	*4593.44*	*12269.50*	*4697.63*	*7812.50*
Weedicide and application (labour) cost, Rs.ha^{-1}*	*2550.00*	*2550.00*	*2550.00*	*2550.00*
Irrigation and labour cost Rs.ha^{-1} (7 irrigations)	*2657.81*	*2657.81*	*2657.81*	*2657.81*
Manual harvesting cost, Rs.ha^{-1} (for 6 cuttings)	*46,875.00*	*46,875.00*	*46,875.00*	*46875.00*
*Total cultivation cost, Rs.ha^{-1} (USD.ha^{-1})***	*1,65,605.50 (USD2590)*	*1,73,281.56 (USD 2710)*	*1,68,147.19 (USD 2630)*	*1,68,824.56 (USD 2640)*
Yield (6 cuttings), t.ha^{-1}	*262.79*	*250.42*	*279.13*	*255.25*
*Income Rs.ha^{-1} @Rs. 1500/tonne (Green fodder), (USD.ha^{-1})***	*3,94,185.00 (USD 6165)*	*3,75,630.00 (USD 5875)*	*4,18,695.00 (USD 6548)*	*3,82,875.00 (USD 5988)*
Net returns, Rs.ha^{-1} (USD.ha^{-1})	*2,28,579.50 (USD 3575)*	*2,02,348.44 (USD 3165)*	*2,50,547.81 (USD 3918)*	*2,14,050.44 (USD 3348)*
B:C Ratio (Benefit:cost ratio)	*2.38:1*	*2.17:1*	*2.49:1*	*2.27:1*
% Saving in time as compared with manual method	*77.78 %*	*33.33 %*	*75.00 %*	*---*

**Labour cost @Rs.31.25 per hour, **1 USD = 63.94 Indian rupees*

The green fodder yield was found maximum for sugarcane cutter planter machine as 279.13 t·ha^{-1} and for semi-automatic potato planter, vegetable transplanter and control were 262.79, 250.42 and 255.25 t·ha^{-1} respectively and the effect was found to be significant at 5 % level of significance. The reason for higher plant population and better yield for sugarcane cutter planter was placement of sets at proper depth and in good moisture and afterwards coverage with soil properly due to which germination was uniform and crop stand was better. Moreover plant to plant spacing was also uniform and mean number of plants/ha were also higher for Napier-Bajra sown with sugarcane cutter planter. The mean plant to plant spacing for sugarcane cutter planter, vegetable nursery transplanter, potato planter and control method were 668.37, 756.73, and 725.0 and 742.15 mm the effect was significant at 5 % level of significance.

The economic analysis was also done for three planters and is shown in Tab. 3. In this analysis, manual method of planting was also taken. Tab. 3. shows that benefit cost ratio was maximum for sugarcane cutter planter as 2.49:1 and minimum for semi-automatic vegetable nursery transplanter as 2.17:1.

Net returns per ha for semi-automatic potato planter, semi-automatic vegetable nursery planter, semi-automatic sugarcane cutter planter and control were Rs. 2,28,579.50, 2,02,348.44, 2,50,547.81 and 2,14,050.44 respectively. The saving in time with semi-automatic potato planter, semi-automatic vegetable nursery planter and semi-automatic sugarcane cutter planter as compared with manual sowing method were 77.78 %, 33.33 %, and 75.00 % respectively. The graphical representation of effect of three different planters and manual sowing method on yield and net returns from Napier Bara crop is shown in Fig. 8. The higher yield from Napier Bajra crop sown by sugarcane cutter planter can be attributed to higher depth of set placement, closer plant to plant spacing and higher plant population obtained as compared to other three planters/planting techniques.

CONCLUSIONS

1. The number of plants/ha for sugarcane cutter planter, vegetable transplanter, potato planter and control were found to be 23,563, 19,895, 21,442 and 20,826 respectively.
2. The green fodder yield was maximum for sugarcane cutter planter machine as 279.13 $t.ha^{-1}$ and for semi-automatic potato planter, vegetable transplanter and control were respectively 262.79 $t.ha^{-1}$, 250.42 and 255.25 $t.ha^{-1}$.
3. Benefit cost ratio for sugarcane cutter planter, vegetable nursery transplanter, potato planter and control were 2.49:1, 2.17:1, 2.38:1 and 2.27:1 respectively. The saving in time with semi-automatic potato planter, semi-automatic vegetable nursery planter and semi-automatic sugarcane cutter planter as compared with manual sowing method were 77.78 %, 33.33 %, and 75 % respectively.

BIBLIOGRAPHY

[1] Anonymous. 2015. Available through: www.icar.org.in/files/forage-and-grasses.pdf 1356-57 9. [Accessed date: 28-5-2015].

[2] Anonymous. 2014. *Package of practices for crops of Punjab Rabi, Package of practices for crops of Punjab, Khaif*, Punjab Agricultural University, Ludhiana (Punjab), India.

[3] Khobragade, B.V., Bokade, N.A., Jadhavrao, K.S., Chaudhri, M.S. 2011. Feasibility testing of tractor operated seed drill for sowing sorghum. *International Journal of Agricultural Engineering*, 4(2): 176-178

[4] Krishna, K.M., Ahmed, S.R. 2010. Soluble oxalate content accumulation and yield of certain Hybrid Bajra Napier genotypes during summer and their influence on animal diet. A*dvance Research Journal of Crop Improvement* 1(2): 153-155

[5] Mago, L. 2010. The costs of Sweet Sorghum (*Sorghum Vulgare Sacchartum*) production, according to the level of the farm's mechanization. *Agricultural Engineering* 4**:**71-79.

[6] Premaratne, S., Premalal, G.G.C. 2006. Hybrid Napier (*Pennisetum perpureum x Pennisetum americarnum*) var. CO-3: A resourceful fodder grass for dairy development in Sri Lanka. *The Journal of Agricultural Sciences*, 2(1): 22-33

KOMPARATIVNA POLJSKA PROCENA RAZLIČITIH MEHANIZOVANIH TEHNIKA SADNJE NAPIER-BAJRA

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Sažetak: Prema 17. popisu stoke (2003) ukupna stočna populacija se sastoji od 485 miliona grla, a brojno stanje živine iznosilo je 489 miliona. Očekuje se da se ukupna populacija poveća u narednim godinama za 1.23%. Trenutno u zemlji postoji neto deficit zelene stočne hrane od 61.1%, 21.9% suvih žetvenih ostataka i 64% hraniva. U Indijskom istraživačkom institute za pašnjake i krmno bilje (*IGFRI*), Jhansi, razvijeno je preklapanje sistema ratarenja da bi se zadovoljile potrebe farmi muznih krava za zelenim hranivima tokom cele godine. Napier-Bajra je višegodišnja biljka i posle sadnje daje stočnu hranu naredne 2-3 godine. Značajan uticaj na prinos ima i tehnika sadnje. Zato je ova studija izvedena da oceni performanse tri sadilice: poluautomatske sadilice, sadilice reznica, sadilice povrća i sadilice krompira za sadnju Napier- Bajra varieteta PBN-233. Broj biljaka po hektaru za sadilicu reznica, povrća, krompira i kontrolu iznosio je 23.563, 19.895, 21.442 i 20.826, redom. Najveći prinos zelene stočne hrane postignut je sadilicom reznica šećerne trske (279.13 $t \cdot ha^{-1}$), a sa poluautomatskom sadilicom krompira, sadilicom povrća i kontrolom prinosi su iznosili 262.79, 250.42 i 255.25 $t \cdot ha^{-1}$, redom. Odnos isplativosti investicije iznosio je 2.49:1, 2.17:1, 2.38:1 i 2.27:1, redom. Ušteda vremena u poređenju sa ručnom sadnjom je bila 77.78 %, 33.33 % i 75.00 %, redom.

Ključne reči: *hybrid, Napier-Bajra, sadilica šećerne trske, poljski kapacitet, prinosi.*

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DEVELOPMENT AND PERFORMANCE EVALUATION OF PLANTAIN PEELER CUM SLICER

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Abstract: Peeling and slicing of green mature plantains of *Nendran* variety is labour intensive and costly. Based on the physical and mechanical properties of green mature plantain the peeler cum slicer was developed. The peeling unit of the fabricated machine consists of feeding cylinders, peeling blades, conical throat and splitters. The green plantain fed into the feeding cylinder was pushed down by a pushing mechanism. Slicing unit consists of a cylindrical guide, slicing disc and blade. Slicing was achieved by rotating the disc at 300 min^{-1}. Average peeling efficiency and material loss were obtained at 88.94% and 13.69%, respectively. Diameter of feeding cylinder was significant at 1% ($P<0.01$) level for overall capacity of machine. The overall capacity, slicing efficiency and effective capacity of the plantain slicer was found to be 89.27 $kg\cdot h^{-1}$, 89.16 $kg\cdot h^{-1}$ and 79.59 $kg\cdot h^{-1}$, respectively. The capacity of the developed peeler cum slicer was four times higher than manual operation.

Key words: *peeler, slicer, banana, effective capacity, material loss*

INTRODUCTION

Fruits and vegetables play an important role in human diet and nutrition. They are indispensable sources of essential dietary nutrients, vitamins and minerals besides providing crude fiber. India is the largest producer of fruits and vegetables next to China. But due to lack of post harvest handling and processing facilities around 30% of the total production is lost every year [1]. The post harvest method need to develop to minimize the losses [2]. However, the thrust should be to process and convert such perishable

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commodities into value added products that can be stored for extended periods there by reducing losses and making them available through out the year.

Banana (*Musa paradisiaca*) is one of the oldest tropical fruits cultivated by man from prehistoric time in India with great socio-economic significance, interwoven in the cultural heritage of the country. It is the fourth important food crop in terms of gross value after paddy, wheat and milk products and forms an important crop for subsistence farmers. In Kerala banana is cultivated in the entire state and is an integral part of homestead farming system. It is a vegetable as well as fruit apart from being used for the preparation of various value added products. It provides a more balanced diet than any other fruit or vegetable. The green banana which becomes palatable after cooking is popularly referred as plantains, and is a staple food in coastal region of the country especially in Kerala, while the fresh fruit we consume is referred as dessert banana.

In India crop production has been steadily increasing due to advances in production technology, but improper post harvest handling and storage results for high losses [3]. Hence, the long-term objective of our country's economic development is a good balance between a strong industrial sector and a resilient agricultural sector. The development of micro, small and medium scale rural agro industry is seen as a strategic step towards achieving this goal. There are large numbers of micro and small scale food processing enterprises run by farmers, which produce a wide variety of processed foods. Processed foods or snack foods may be described as mini meals in between main meals. Snacks like banana chips light to eat and serve a variety of useful purposes in our day to day life. Banana chips making has already developed into a cottage and small scale industry in Kerala and the product is in high demand in India as well as abroad, especially in Middle East countries. The quality of the products can be monitored by online system with FT-NIR Spectroscopy [4]. There is great potential for this to be developed further, exploiting the domestic and fast increasing export demand.

Peeling and slicing of the well matured unripe plantain is a difficult operation for an unskilled person and also time consuming. Peeling is the removal of skin from green mature plantain. Slicing is carried out to reduce the size of product so as to enable it to suit the processing and consumer requirements. At present, peeling and slicing of plantain is done manually by stainless steel knives. This conventional method poses danger to operator's finger by inflicting injury. Frying quality of chips depends greatly on the uniformity of the wafers. The existing conventional method does not produce chips of uniform size. The output capacity of the system is less and the whole process is time consuming and labor intensive.

The knowledge of some important physical and mechanical properties of fruits is necessary for the design of various food processing equipments [5, 6]. In order to eliminate the drudgery involved in manual peeling, avoid injury to workers, increase efficiency and maintain high quality standards and hygiene to the prepared chips, an attempt was made at Kelappaji College of Agricultural Engineering and Technology, Tavanur to develop a plantain peeler cum slicer in terms of capacity, peeling efficiency and material loss.

MATERIAL AND METHODS

The plantain peeler cum slicer consists of feeding unit, peeling unit, pushing unit, collection unit, slicing unit and frame assembly as shown in Fig.1.

Feeding unit. The feeding unit consists of three cylindrical guides of different diameters placed 120° apart fixed to a sleeve using three equal length mild steel flats of 28×3.15×750 mm. A cylindrical sleeve of 48×34 mm (diameter × length) was mounted on 500 mm vertical pillar. The rotation of the cylindrical guide is possible by rotating the sleeve. Three stainless steel pipes of diameters 42, 47 and 54 mm, height 200 mm each and thickness 2 mm were used for the fabrication of cylindrical guide.

Peeling unit. It is the main unit of the peeler which separates the peel from the pulp. Three high carbon steel blades of width 25 mm were bent to form circular type openings of diameters 28, 32 and 37 mm for respective cylindrical guides through which plantain passes during the peeling operation. Each cylindrical guide was connected to a conical throat of 50 mm height and 60 mm base diameter using splitter blades. The peeling blades were welded over these conical throats. Three splitting blades of medium carbon steel with length 140 mm and thickness 1 mm was welded over each throat of the peeling unit to split the peel after the peeling operation.

Pushing unit. The main parts of pushing unit are piston, rack and pinion and ratchet and pawl. The lowering and lifting of the piston is done by this unit. Ratchet and pawl is a device consisting of a toothed wheel engaged with a pivoting, spring loaded finger called a pawl that permits it to move in one direction and preventing motion in opposite direction. The teeth are uniform, having a moderate slope on one edge and a much steeper slope on the other edge. When the wheel rotates in one direction, the pawl slides over the teeth, and in opposite rotation, it catches in the teeth. The rack is a flat, toothed part of 3 mm pitch and 300 mm long. The pinion was fitted with 18 teeth. It converts the applied rotary motion to linear motion. The upward and down ward motion of the piston inside the cylindrical guide was performed by these two mechanisms.

Collection unit. The collection unit consists of outlet chute and a collecting tray. The outlet chute was made of 16 gauge Galvanized Iron sheet with 45° inclination towards the horizontal to facilitate easy discharge. Collecting tray of 300x300x300 mm was made from Aluminium sheet of 1 mm thickness. The peeled plantain slides downward through the outlet chute into the collecting tray.

Slicing unit. Slicing unit consists of a cylindrical guide, slicing disc and blade. Peeled plantain was fed to the slicing unit through the cylindrical guide of 37 mm diameter and 150 mm length. About 40 x 15 mm stainless steel blade was mounted over

110 mm diameter disc of 1.8 mm thickness. Slicing was achieved by rotating the disc at 300 min^{-1}. The slicing unit was powered with 10 A, 12 VDC motor with 32 $kg\cdot cm^{-1}$ torque.

Frame assembly. The frame supports the entire machine component to perform its operation satisfactorily. It was fabricated using ISA 31x6.3 mm MS section. On the frame assembly, units like pushing unit, feeding unit, peeling unit, peeled plantain outlet and slicing unit were mounted.

Performance evaluation of peeling unit. Matured *Nendran* procured from the local market were used for conducting the experiment. The plantains were graded into three sets according to their size. The two ends of the matured plantain of *Nendran* variety were chopped off and then fed through the respective cylindrical guides of diameters 42, 47 and 54 mm. Peeling was achieved by the cutting action of the circular blade followed by splitting of the peels by the splitter. The peeled plantains falls down through the inner throat and collected in the collecting tray. The split peels slides through the outer conical throat were placed in the discard tray. The time required for operation was noted and the capacity was calculated. All the experiments were replicated five times and the average value was recorded. A comparison between manual and mechanical peeling was also carried out.

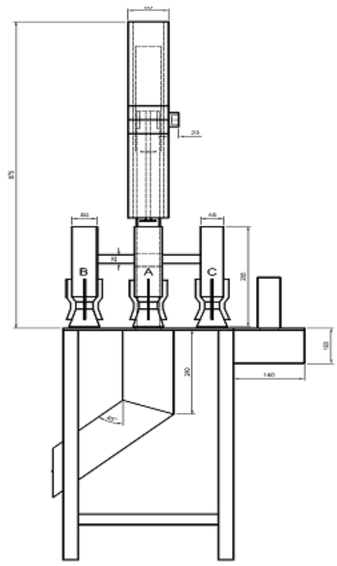

Figure 1. Plantain peeler cum slicer

Capacity. The capacity of the peeler which is the kilogram of peeled plantain produced by the machine in one hour was calculated by noting the weight of the peeled plantain produced and the time taken for the same. It was expressed in $kg \cdot h^{-1}$.

Peeling Efficiency. The initial weights of the different samples of plantain were taken. Then each sample was subjected to peeling action. After peeling, the weight of the peeled product and the peel obtained were noted. The peel remaining on the plantain was removed manually for each of the samples and the weights were noted. Peeling efficiency was then calculated using the formula [7].

$$Peeling\ efficiency = (X-Y) \times 100 / X \qquad (1)$$

where:

X [g] - weight of the total peel,

Y [g] - weight of peel remaining on plantain to be removed manually after mechanical peeling.

Material loss. Material loss for each sample was calculated based on the following formula:

$$Material\ loss\ (\%) = Z / (W+Z) \qquad (2)$$

where:
Z [g] - weight of flesh obtained from the peel,
W [g] - total weight of plantain after mechanical peeling.

Performance evaluation of slicing unit. The peeled samples were fed to the cylindrical guide of the slicing unit to achieve slicing operation. The slices were collected in a tray and kept below the blade set. The time required for the operation was noted and operating capacity, percentage damage and slicing efficiency was evaluated.

Overall Capacity. The operating capacity of the fabricated slicer was calculated by weighing all the cut slices irrespective of damage per unit time.

Slicing Efficiency. The efficiency of slicer was evaluated by weighing the damaged and round slices separately and using the expression [8].

$$Slicing\ Efficiency\ (\eta), \% = \frac{Weight\ of\ all\ slices - Weight\ of\ damaged\ slices}{Weight\ of\ all\ slices} \times 100 \tag{3}$$

Percentage damage. The percentage damage of the slicer was evaluated using the following expression:

$$\text{Percentage damage, } \% = \frac{\text{Weight of damaged slices}}{\text{Weight of all slices}} \times 100 \tag{4}$$

Effective capacity. The effective capacity found by using the expression [9].

$$Effective\ capacity = Overall\ capacity\ x\ \eta/100 \tag{5}$$

Statistical analysis. Data were analyzed using AGRES software. Data of experiment were analyzed by a randomized block design using factorial arrangements of treatments [10].

RESULTS AND DISCUSSION

Capacity. The capacity of the peeler for 42, 47 and 54 mm diameter feeding cylinder are presented in Tab 1. The over all capacity was found to be 34.21, 49.74 and 68.48 $kg \cdot h^{-1}$ for 42, 47 and 54 mm diameter cylindrical guides, respectively.

From the table, it was observed that the capacity of the machine increased with the diameter of feeding cylinder. Maximum capacity was obtained using 54 mm diameter cylindrical guide and minimum for 42 mm. This may be due to the size of the plantain increases with weight. But there is no significant change in time taken for peeling plantains through a single cylindrical guide.

The overall capacity were statistically analyzed and presented in Table 2. From the table, it was observed that the feeding cylinder diameter was significant at 1% (P<0.01) level.

Peeling efficiency. The peeling efficiency of the machine is presented in Fig.2. The average peeling efficiency of the machine using 42, 47 and 54 mm diameter feeding cylinder were obtained as 89.19, 88.27 and 89.37%, respectively.

From the results, it was revealed that there is no significant (P>0.01) variation in the efficiency of peeling operation (Tab. 2). For a particular cylindrical guide, peeling efficiency increases if the plantain correctly fits into the guide. Lower peeling efficiency was observed in plantains with slightly curved shape.

Material loss. The material loss or flesh loss of the plantain during mechanical peeling was found and presented in Fig. 2. It was revealed that, the material loss depends on the shape and size of the plantain. The percent material loss for 42, 47 and 54 mm cylinders were calculated as 13.27, 13.18 and 14.63% respectively. For a particular cylindrical guide, it was found that the percent material loss increases with weight of the plantain. This is due to the constant size of the peeling blade. From the Tab. 2, it was observed that feeding cylinder diameter was not significant (df=2; F=. 0.80) for material loss.

Table 1. Capacity of the peeler

Sl. no.	*Weight of peeled plantain [g]*	*Time taken for peeling [s]*	*Capacity of the developed peeler [kg·h^{-1}]*
42 mm diameter feeding cylinder			
1.	*117.27*	*14.05*	*30.04*
2.	*116.84*	*13.13*	*32.03*
3.	*114.31*	*10.25*	*40.14*
4.	*106.77*	*12.95*	*29.68*
5.	*112.83*	*10.37*	*39.16*
		Mean	*34.21*
47 mm diameter feeding cylinder			
6.	*148.07*	*11.27*	*47.29*
7.	*160.54*	*12.21*	*47.33*
8.	*149.64*	*10.42*	*51.69*
9.	*151.53*	*10.33*	*52.80*
10.	*147.42*	*10.70*	*49.59*
		Mean	*49.74*
54 mm diameter feeding cylinder			
11.	*221.49*	*13.45*	*59.28*
12.	*218.04*	*12.78*	*61.41*
13.	*229.28*	*10.53*	*78.38*
14.	*220.52*	*11.67*	*68.02*
15.	*225.45*	*10.77*	*75.35*
		Mean	*68.48*

Performance evaluation of slicing unit. The slicing unit was evaluated in terms of overall capacity, slicing efficiency and percent damage. Results are furnished in Tab. 3, 4 and 5 for overall capacity, slicing efficiency and percent damage, respectively.

The overall capacity, slicing efficiency, percentage damage and effective capacity of the plantain slicer were found to be 89.27 kg·h^{-1}, 89.16%, 10.82% and 79.59 kg·h^{-1} respectively.

Table 2. Analysis of variance for overall capacity, peeling efficiency and material loss

Variable	Capacity		Peeling efficiency		Material loss	
	df	F	df	F	df	F
Cylinder diameter	2	177.53**	2	0.1871NS	2	0.8020NS
Error	5.05		4.08		2.01	
Total	244.67		2.42		1.40	
SEd	1.83		1.65		1.15	
CV, %	4.46		2.26		10.25	

Table 3. Overall capacity of slicer

Sl. No.	Weight of peeled plantain [g]	Time taken for slicing [s]	Over all capacity [$kg \cdot h^{-1}$]
1.	54.08	6.38	88.20
2.	51.34	5.47	89.34
3.	52.85	6.29	88.09
4.	45.94	4.8	89.55
5.	45.2	3.99	91.17
		Mean	89.27

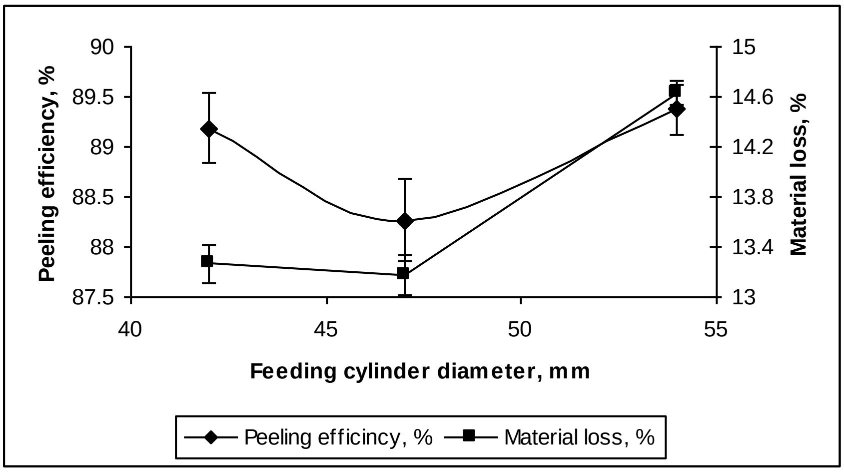

Figure 2. Effect of feeding cylinder diameter on peeling efficiency and material loss

Table 4. Efficiency of slicer

Sl. No.	Weight of all slices [g]	Weight of damaged slices [g]	Efficiency [%]
1.	323.03	29.47	90.87
2.	260.45	28.61	89.01
3.	340.65	37.55	88.97
4.	345.79	39.41	88.60
5.	350.95	40.74	88.39
		Mean	89.16

Table 5. Percentage damage of the slicer

Sl. No.	*Weight of all slices [g]*	*Weight of damaged slices [g]*	*Percentage damage [%]*
1.	*323.03*	*29.47*	*9.12*
2.	*260.45*	*28.61*	*10.98*
3.	*340.65*	*37.55*	*11.02*
4.	*345.79*	*39.41*	*11.39*
5.	*350.95*	*40.74*	*11.60*
		Mean	*10.82*

Comparative evaluation of manual and mechanical peeling cum slicing operation. As illustrated in Tab. 6 results of manual peeling indicates that a skilled labour can peel 14.8 kg plantains per hour and slice 18.52 kg·h^{-1}. Under the same conditions, the fabricated peeler could peel 48.9 kg·h^{-1} and slice 89.63 kg·h^{-1}. The peeling and slicing capacity of the fabricated machine is found to be four times more effective than manual peeling and slicing. Besides, peeling and slicing efficiency is high. Also, even and more uniform slices can be obtained by the fabricated machine. The machine eliminates the drudgery involved in manual peeling and slicing operations and save time. The machine is simple in construction and operation and required only one person to operate it.

Table 6. Comparison of manual and mechanical peeling cum slicing operation

Sl No.	*Time required for peeling of one sample [s]*		*Time required for slicing of one sample [s]*	
	Manual	*Mechanical feeling using 47 mm feeding cylinder*	*Manual*	*Mechanical*
1.	*36.5*	*11.4*	*29.8*	*6.8*
2.	*35.9*	*10.7*	*28.5*	*5.2*
3.	*36.0*	*10.9*	*28.8*	*5.7*
4.	*36.2*	*11.2*	*29.5*	*6.4*

CONCLUSIONS

In India, the peeling and slicing of plantain is carried out manually and no means of mechanical peeling and slicing device has been commercialized. The conventional method of peeling and slicing is done by using stainless steel knives. This poses danger to operator's finger by inflicting injury and also does not produce chips of uniform size. Peeling was achieved by the cutting action of the circular shaped blade that would force the peel from the plantain as it passes through the mechanism. The slicing unit was powered with 10 A, 12 VDC motor with 32 kg·cm^{-1} torque. The actual capacity of the peeling unit was calculated as 18.54, 25.98 and 36.87 kg·h^{-1} respectively for small, medium and large sized plantains. The machine eliminates the drudgery involved in manual peeling and slicing operations and save the time as compared to conventional method.

BIBLIOGRAPHY

[1] Sudheer, K.P., Indira,V. 2007. *Post Harvest Technology of Horticultural Crops*. New India Publishing Agency, New Delhi. pp. 2.

[2] Ravi, P., Venkatachalam, T., Rajamani, M. 2015. Decay Rate kinetics of Ozone Gas in Rice Grains. *Ozone: Science & Engineering*, (Accepted). DOI: 10.1080/01919512.2015.1040912.

[3] Pandiselvam, R., Thirupathi, V. 2015. Reaction kinetics of Ozone gas in Green gram (Vigna radiate). *Ozone: Science & Engineering*, 37, 1-7. DOI: 10.1080/01919512.2014.984158.

[4] Ravi, P., Venkatachalam, T., Palanisamy, V. 2014. Fourier transform near-infrared spectroscopy for nondestructive and rapid measurement of moisture content of paddy. *Poljoprivredna tehnika*, *39*(3), 31-40.

[5] Ravi, P., Venkatachalam, T. 2014. Important engineering properties of paddy. *Poljoprivredna tehnika*, *39*(4), 73-83.

[6] Rangaraju, V., Vijayaram, E.N., Sulthan, S., Veerapandian, C. 2015. Modeling the Mass of Banana Fruit by Geometrical Attributes. *Poljoprivredna tehnika*, 2, 91-99.

[7] Radhakrishnan Setty, Vijayalakhmi, M.R., Usha Devi, A. 1993. Methods for peeling fruits and vegetables; A critical evaluation. *Journal of Food Science and Technology,* 300(3), 155-162.

[8] Kacharu, P.P., Balsubramanian, D., Kotwaliwale, N. 1996. Design, Development and Evaluation of Rotary slicer for Raw banana chips. *Agricultural mechanization in Asia, Africa and South America,* 27(4), 6-12.

[9] Balasubramanian, V.M., Viswanathn, R., Sreenarayanan, V.V. 1993. Design, Development and Evaluation of a Cassava chipper. *Agricultural mechanization in Asia, Africa and South America*, 24, 60-64.

[10] Pandiselvam, R., Amreena, J.N.J., Parthasarathi, G., Rajesh, K., Kaveri, G. 2014. Development and performance evaluation of mobile irrigator for dry land agriculture. *Poljoprivredna tehnika, 39*(3), 53-62.

RAZVOJ I OCENA KARAKTERISTIKA MAŠINE ZA LJUŠTENJE I REZANJE

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Sažetak: Ljuštenje i rezanje zelenih zrelih banana varijeteta *Nendran* je veoma intenzivan i skup postupak, Na osnovu fizičkih i mehaničkih osobina zelenih zrelih banana razvijena je mašina za ljuštenje i rezanje. Jedinica za ljuštenje ove mašine se sastoji od dostavljačkih cilindara, noževa za ljuštenje, konusnog grla i razdeljivača. Zelene banana se ubacuju u privodni cilindar i guračem potiskuju dole. Rezni uređaj se sastoji od cilindrične vođice, režućeg diska i noža. Rezanje se postiže rotacijom diska sa 300 min^{-1}. Srednja efikasnost ljuštenja i gubici materijala su iznosili 88.94% i 13.69%, redom. Uticaj prečnika privodnog cilindra bio je značajan na nivou 1% (P<0.01) za ukupni kapacitet mašine. Ukupni kapacitet, efikasnost sečenja i efektivni kapacitet sekača iznosili su 89.27 kg·h^{-1}, 89.16 kg·h^{-1} i 79.59 kg·h^{-1}, redom.

Ključne reči: *ljuštenje, rezanje, banana, efektivni kapacitet, gubici*

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THE DEVELOPMENT OF VERTICAL PATTERNATOR TO EVALUATE THE HYDRAULIC SPRAYERS

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Abstract: In Egypt, it could be not able to test the vertical distribution for agriculture sprayer machines this may be due to the poor measuring instruments such as vertical patternator. The aim of the current research is develop and evaluate an inexpensive vertical patternator for hydraulic sprayers. The current research study carried out in laboratory of agricultural engineering dept., faculty of agriculture, kafr El-Sheikh University. The vertical patternator manufactured and made from the local material under laboratory and work station in kafr El Sheikh University. The tests and the evaluation of the patternator included two main parameters. The first treatment was evaluation the three vertical sprayers under laboratory conditions. As well as, the second treatment was evaluation two different measured methods to determine the efficiency of the sprayer by using the CV %. The results indicated that, the Tee-jet XR 110-3 *VP* nozzles gave the highest percentage value of spray liquid captured compared to Hardi110-02 LS and LU110-04 nozzles. The development patternator captured more spray liquid due to increase of the operating pressure of spray liquid. The t-test value for LU 110-04 nozzle was -1.48 with standard error (SE) 0.23 and probability P-value 0.89. It could be used the automatic method to estimate the CV % and it's easy to apply. As well as, there are no different effect between manual and automatic method at the volume application rate 475 l·ha $^{-1}$, 960 l·ha $^{-1}$ and 1150 l·ha $^{-1}$ for determination of the spray uniformity or CV %.

Key words*: spray distribution, patternator*

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INTRODUCTION

The use of patternator relates principally to achieving a uniform volume distribution pattern at a horizontal surface, and therefore may only be relevant for flat fan hydraulic pressure nozzles designed to achieve this. Vertical and horizontal movements of boom sprayers represent one of the elements affecting the quality of pesticide distribution and the effectiveness of the treatments. Vertical movements produce variations of the height of the nozzles, determining, as a consequence, areas over-sprayed by contiguous nozzles and areas under-sprayed or unsprayed: in any case the quantity of product distributed at ground differs from the optimum value. The assumption that biological efficacy, particularly for foliar and insect targets, can be predicted by patternator measurements made in a static laboratory situation is highly questionable [7]. Measurements of spray distribution by a patternator do not relate directly to deposition on the actual biological target which will vary greatly with the application. The actual biological target area ranges from the soil to the ear or stem of a cereal plant with insects, fungi and weeds presenting vastly differing type of target [1]. Also the target area for deposition against a particular pest can vary even with the particular chemical used depending on its mode of action. For example, to optimally control an insect living on an under-leaf surface, contact, systemic and vapour acting chemicals would need to be applied to different specific target areas for maximum efficiency. Different nozzles have been shown to give different types of overall deposit pattern. The deposit ratio between horizontal and vertical targets differs significantly between flat fan and air induction nozzles. It has long been known that air assisted sprayers also change these deposit ratios and the effect will vary differently with different dynamic factors [3] and [8]. Thus a simple two-dimensional measurement of the horizontal deposition profile may well be very misleading regarding predicting deposition on (complex) three-dimensional targets**.** [2] specifically suggests that biological efficacy of various nozzles used for band spraying was not related to the measured horizontal spray distribution pattern. [2] studied the effects of spray boom deflection, wind velocity, and wind direction on spray pattern displacement (SPD) of extended range of 110-0 fan nozzles by using patternator. Tests were conducted at four nozzle pressures of 139, 208, 313 and 383 kPa . At each pressure, tests were conducted at four winds conditions and including combinations of both cross and head wind However, coefficient of variation (C.V., %) values of 8.5% to 13.5% obtained from these tests indicated uniform or acceptable coverage. [5] and [6] indicated that the spray distribution is improved by increasing nozzle size, pressure and reduces the nozzle height. The type of nozzles is very important parameters which affect the distribution of pattern (C.V.%). The selection of nozzles may be reduced the losses of spray dose and gives good distribution of pattern. Static indoor patternator measurements ignore the dynamic effects of boom and air movement on spray distribution with air movements and micro-climatic conditions greatly influencing deposition patterns (particularly with more biologically efficient smaller droplets where turbulent transport is often a very significant factor in spray distribution and deposition). The importance of dynamic factors and states: ‘Spray distribution, measured under static conditions on a patternator, does not represent the pattern achieved in routine dynamic applications. Each specific sprayer configuration defined by nozzle type, spraying height, pressure and speed yields in a specific horizontal dynamic distribution pattern which is unpredictable and shows longitudinal strips of distinct deposit levels on targets within the sprayed area. A number of factors affect the deposition and retention of pesticide on the plants. The examples of such factors are canopy structure of the target crop, spray application factors and properties of the sprayed liquid and air-assistance to hydraulic boom of the sprayers. Leaf morphological features such as shape, leaf orientation and leaf age may also affect retention. A part of the spray can be lost during the application before the droplets are deposited on plants or soil. Droplets can be transported out of the sprayed field by spray drift [4].

Objectives. The main objectives are developed and evaluated of an inexpensive vertical patternator that researchers or growers can construct at their farm workshop under Egyptian conditions. As well as, increase the efficiency of application by improving the technical condition of sprayers. Reduce pesticide application costs for growers by correct targeting. Also, decrease environmental pollution.

MATERIAL AND METHODS

The vertical patternator: The developed vertical patternator was constructed and manufactured in the laboratory of agricultural engineering department, faculty of agriculture, Kafr El-Sheikh University. Nine 35 cm x 100 cm wide fly screens were connected via hooks to two 35 cm high, 3 x 1.5 cm aluminum U-section. A small gutter was attached, at an angle, to the bottom edge of each screen. The gutter sloped to one end where a plastic hose was connected which ran down to a box containing through the flexible polyethylene 10 mm tube diameter to the 700 mm length and 80 mm diameter cylinders. The frame was constructed in two halves for ease of assembly. The collecting cylinders fixed in aluminum frame and the polyethylene 10 mm tubes were fixed at the top of the collecting cylinders. As well as, the mechanical valve was fixed in the bottom of each collecting cylinders. The mobile unit which driven by the driver pulley that mounted with the stepper motor. The stepper motor was data logger was constructed upon the top of collecting cylinders. As well as, it was moved upon the top of center of the collecting cylinders. The Kimo software program was used to control of the steps for mobile unit. *LASER* distance instrument was used and fixed in vertical position on the mobile unit to measure the height of the collecting liquid sprayed as shown in figure 1.

Miscellaneous Transmission Systems: The belt drive is effective in applications where a small payload is moved at high linear velocities with a high acceleration rate over a relatively short distance with a relatively low accuracy. The linear velocity for the x-axis is calculated with Eq. 1. A cylinder diameter of 80 mm was specified in the patternator system design constraints.

The angular velocity for the pointing mechanism must be proportional to the velocity and acceleration of the x, axis since the Laser may be cropped if the linear velocity of the x axis is faster than the rotational velocity of the pointing mechanism. From Eq. 1, the linear velocities were 2.25 $m \cdot s^{-1}$, 1.5 $m \cdot s^{-1}$ and 1.15 $m \cdot s^{-1}$ at operating time 60 s , 90 s and 120 s, respectively. The optimum linear velocity was 1.5 $m \cdot s^{-1}$ which gave a good number of operating pulses. The number of operating pulses is expressed as the number of pulse signals that adds up to the angle that the motor must move to get the work from point A to point B. The motor speed limitations may occur due to setting of Kimo software program.

$$v = \frac{n.(D + d - 1)}{t} \quad (1)$$

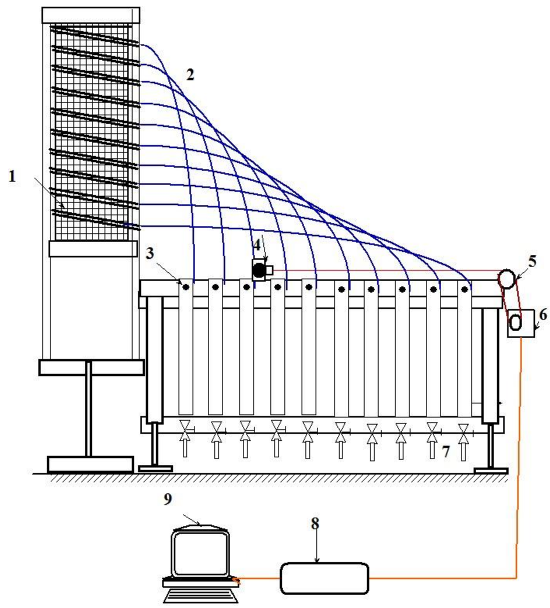
where:

n	[-]	- number of collecting cylinders to be inspected,
D	[mm]	- cylinder diameter,
d	[mm]	- distance between the cylinders,
t	[s]	- inspection time.

Ultrasonic sensor: The measured distance range for the above mentioned Atrium Ultrasonic sensor is 40 mm to 27000 mm. To simplify the sensor procedure, the sensor could be advantageous in a variety of applications, including distance measuring in tight spaces and liquid level control for tubs in patternator.

Spray liquid measurement level setup: The Atrium Ultrasonic sensor was mounted on the belt which driven by steeper motor. The electric steeper motor was moved from the end of the lift side to the right side in the patternator. In addition, the eclectic motor controlled by the Kimo software program and it was programmed to move over every tube in the patternator as shown in figure 1. The Laser sensor was moved over the top of every tube in the patternator and measured the distance that indicated the spray liquid levels for each tube. These distances of the spray levels for each tube recorded to calculate the spray volume for each tube, flow rate, and coefficient of variation CV %. The Voltcraft DL-120th data logger was used to measure the relative humidity and the temperature. As well as the flow-rate and coefficient of variation percentages (CV %) were determined. By computer analysis, from the levels recorded in the patternator tubes for the single candidate nozzle, calculate the distribution for a 1.8 meter width (i.e. 9 columns) excluding the ends where there is no overlap. The manometer pressure was monitored using a 0-1500 kPa, class 3A pressure gauge.

Procedures: The current research investigates to evaluate the distribution for the development vertical patternator. The vertical patternator comprises a vertical mast which travels through the spray cloud. Droplets are intercepted by a collection device, the resultant liquid then passes through pipes to graduated collection tubes. The collected liquid shows a pattern, it shows how the spray is distributed within the tree, and how much spray goes over the top of the canopy as drift. The sprayer operator can adjust nozzle orientation to improve deposition on the target e.g to the fruit zone rather than wasting spray over the canopy. The spray cloud hit the fly screen, the air passing through and the liquid ran down the front of the screen, into the gutter and then, via the plastic hose into the collecting *PVC* cylinders. The duration of spraying experiments are controlled for each treatment operated at 180 second. Operating spray pressures of 125 kPa, 175 kPa and 250 kPa are applied for three vertical nozzle sprayers to obtain 475 $l \cdot ha^{-1}$, 960 $l \cdot ha^{-1}$ and 1150 $l \cdot ha^{-1}$ application volume rate. The control unit for liquid pressure and flow-rate adjusted before the vertical nozzle used to obtain the operating pressure nozzles for every treatment. All measurements were made spraying water at a temperature of approximately 24° C. Environmental conditions were kept constant at a temperature of 24° C and a relative humidity between 74 and 86 %. A series of experiments were conducted to test the development patternator with manual and automatic measured to see if the new designs would be as accurate as the “standard” manual measured method. The vertical boom sprayer with three different nozzles were tested, Hardi 110-02 LS, Tee jet XR 110-3 VP nozzles and Lechler LU110-04. The above vertical boom sprayer with three different nozzles were simulated as an air ballast sprayer. All sprayers were equipped to spray the above volume rate and three repetitions were carried out for each trial. As well as there are not found any standard vertical patternator under Egyptian conditions to use in the current research. The main treatment was the two different type methods to measure the vertical spray distribution for three different nozzles. Arrangement and statistical analysis of the experiments was according to randomized design.



1- Vertical collectors 2- Polyethylen tubes 10 mm dia.
3- PVC 3 inch dia. tubes 4- LASER instrument connected with small car
5- Pulleys 6- Stepper motor
7- Valves 8- Data logger
9- PC

Figure 1. Diagram of developed vertical patternator to measure the vertical uniformity for hydraulic sprayers

Coefficients of Variation (CV, %): The Excel software program was used and with VB programming programmed the coefficient of variation. The coefficients of variation as the percentage of spray pattern for all nozzles treatment were programmed by using the standard equation and excluding the ends where there is no overlap. The data for every treatment were collected for every treatment conditions. The values of spray volume in every cylinder were used to re-calculate the coefficients of variation percentage. The CV % values were recalculated by using the Eq. 2, 3, and 4 as follows to obtain a good accuracy for the CV % [6].

$$X' = \frac{\sum X_i}{n} \tag{2}$$

$$s = \sqrt{\frac{\sum (x_i - x')^2}{n-1}} \tag{3}$$

$$CV = \frac{s}{x'} * 100 \tag{4}$$

where:
CV [%] - coefficients of variation,
x_i [cm] - height of liquid in the tube,
n [-] - number of patternator columns tubes.

Figure 2. Development vertical patternator to measure the vertical uniformity for hydraulic sprayers

RESULTS AND DISCUSSION

An experiment was conducted to measure the amount recovered by each of the patternator compared to the output of each of the sprayers. Fig. 3 and Tab. 1 show that the development patternator captured the most, averaging 83.25 % of the applied spray. The highest amount recovered was with the Tee-jet XR 110-3 VP nozzles sprayer when 88.3 % was recovered. Tab. 1 presented the percentage of spray captured volume for different nozzles at three operating pressure. It is noticed that, the Tee-jet XR 110-3 VP nozzles gave the highest percentage value of spray liquid captured compared to Hardi110-02 LS and LU110-04 nozzles. Fig. 4 indicated the collected volume for different operating pressure 125 kPa, 175 kPa and 250 kPa. It is clearly that, the development patternator captured more spray liquid due to increase of the operating pressure of spray liquid as shown in Tab. 1.

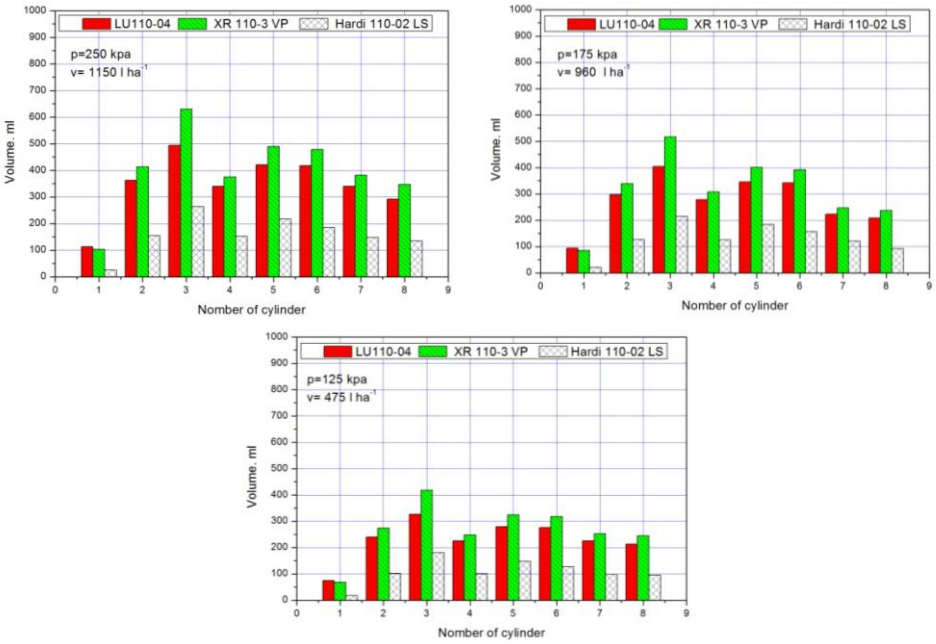


Figure 3: Display the spray volume collected by development patternator under different volume rate and operating pressure

Table 1. The percentage volumes captured in the development patternator at three different operating pressure for different spray type of nozzles

Nozzles	*Pressure [kPa]*	*Flow rate [l·min^{-1}]*	*Volume captured [%]*
Hardi110-02 LS	*125*	*0.39*	*75.6*
Tee-jet XR 110-3 VP		*1.06*	*83.4*
Lechler LU110-04		*0.79*	*81.3*
Hardi110-02 LS	*175*	*0.44*	*83.0*
Tee-jet XR 110-3 VP		*1.14*	*84.1*
Lechler LU110-04		*0.91*	*83.2*
Hardi110-02 LS	*275*	*0.59*	*82.3*
Tee-jet XR 110-3 VP		*1.45*	*88.3*
Lechler LU110-04		*1.36*	*84.6*

Table 2. Statistical analysis of two different measured methods for coefficient of variation percent CV % values in the patternator

Nozzles	*Mean*	*SD*	*SE*	*t-test*	*P-value*	*Significant*
LU-manual	*12.76*	*1.01*	*0.58*	*-1.48*	*0.894*	*Non*
LU-automatic	*13.7 0*	*0.40*	*0.23*	*0.92*	*0.769*	*Non*
XR-manual	*13.63*	*1.40*	*0.81*	*-1.24*	*0.723*	*Non*
XR-automatic	*14.30*	*1.32*	*0.76*	*0.79*	*0.824*	*Non*
Hardi-manual	*15.30*	*1.90*	*1.10*	*-1.67*	*0.889*	*Non*
Hardi-autmatic	*15.73*	*2.02*	*1.16*	*1.12*	*0.966*	*Non*

Table 3. The coefficient of variation CV % values for different nozzles at two different measured methods and three application volume rate

Measuring method	*Application volume [l·ha^{-1}]*	*Lechler LU110-04*	*Tee-jet XR 110-3 VP*	*Hardi 110-02 LS*
Manual	*475*	*15.5*	*13.0*	*12.0*
Automatic		*15.9*	*13.3*	*13.3*
Manual	*960*	*17.1*	*15.5*	*13.4*
Automatic		*17.4*	*15.8*	*14.1*
Manual	*1150*	*15.3*	*13.1*	*12.3*
Automatic		*15.9*	*13.8*	*13.7*

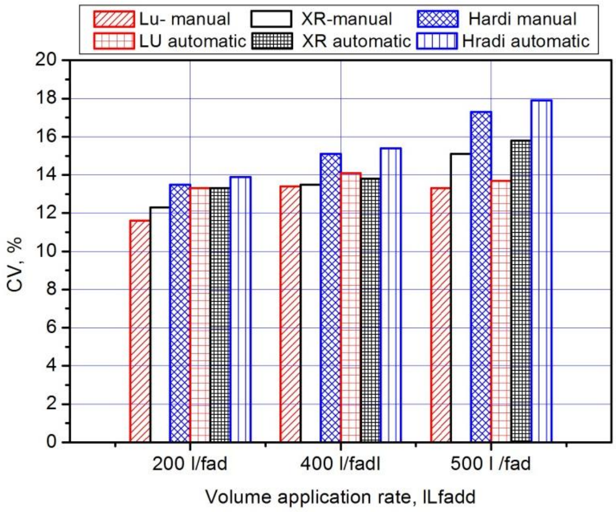


Figure 4. Indicate the CV percent for different nozzles by using development patternator at different volume rate

Coefficient of variation percentage (CV,%): To compare between manual and automatic measured methods for CV percentage, Tab. 2 indicates that the coefficient of variation percent CV % values for different two measured methods in the patternator. It is found that there are no significant different between the automatic and manual measured methods for coefficient of variation percentage. The Origin program version 7 was used to analysis the data. The t-test was used to compare between two measured values of CV %. The t-test indicated that no significant different between two methods for all treatment condition. The t-test value for LU 110-04 nozzle was -1.48 with standard error (SE) 0.23 and probability P-value 0.89. The mean values of CV % for LU110-04 were 12.7 % and 13.7 % at manual and automatic measured respectively. As well as the mean values of CV% for XR nozzle were 13.6 % and 14.3 % at manual and automatic method respectively. The SE value and P-value for XR nozzle were 0.76 and 0.824 respectively. Also, the mean values of CV % for Hardi nozzle were 15.3 % and 15.7 % at manual and automatic method respectively. The above result indicated that, it may able to use the automatic method to estimate the CV % and it's easy to apply. In addition to, the duration time to measure the values in automatic method by using the

LASER sensor may be taking a few seconds compared to the manual measured method. Fig. 4 indicated that the CV percent for different nozzles by using development patternator at different volume rate. It is clearly that the increasing of volume application rate tends to increase the CV % for all nozzles. As well as, it found that there no different effect between manual and automatic method under three volume application rate.

CONCLUSIONS

The result indicated that the development patternator captured more spray liquid due to increase of the operating pressure of spray liquid. After checking both sets of calibration values, it was concluded that the calibrations were performed according to the guidelines issued by the manufacturers of both measuring devices. It is clearly that the influence of different two measured methods of CV % is rather small. This applies for both measuring systems. Although these preliminary tests did produce sufficient results to make some well grounded conclusions. It may be able to put forward some tendencies: firstly, both manual and automatic system are capable of producing stable spray distribution of the pattern and this for each tested nozzle type and size and secondly, the apparatus based on operating pressure is more sensitive of the measuring device. The development patternator may be able to manufacture and use under Egyptian conditions. It will be able to build the own patternator and adjust the sprayers for specific blocks on the farms under local conditions. As well as it will be able to reduce pesticide drift. Also, apply pesticides more effectively leading to better control of insects/diseases as more spray is hitting the target.

BIBLIOGRAPHY

[1] Herbst, A., Wolf, P. 2000. *Spray deposit distribution from agricultural boom sprayers in dynamic conditions*. ASAE Meeting Paper 01 – 1054.

[2] Lund, I., Jensen, P.K. 2002. Application technology for band spraying: Correlation between liquid band distribution and biological efficacy. *Aspects of Applied Biology*, 66. pp 107 – 114.

[3] Richardson, B., Schou, W. C., Kimberley, M.O. 2000. *Defining acceptable levels of spray deposit variation from aerial herbicide applications*. ASAE Meeting Paper

[4] Saha, K.P., Singh, D., Agrawal, K., Bhushanababu, V. 2015. Reduction of Spray Losses to Soil in Soybean. *Agricultural Engineering*. (2015/2), 19 - 28

[5] Sehsah, E.E. .2007. Study effect of forward speed and the spray nozzles types on the spray characteristics of air assistance hydraulic sprayer. M.J.Agric.Eng Vol.24.Nr.1 75-87.

[6] Sehsah, E.E., Kleisinger, S. 2009 Study of some parameters affecting spray distribution uniformity pattern. M. J. Agric Eng. Vol. 26.No. (1) .69-92.

[7] Sehsah, E.E., Kleisinger, S. 2007. Low pressure liquid atomizer for biological pest control. Misr Journal of Agric. Eng. Vol. 24.No. 1. 62-74.,

[8] Urošević, M., Živković, M. 2012. Technical Parameters and Fan Sprayer Quality of Vineyards. *Agricultural Engineering*, 37 (2), 61-69.

RAZVOJ VERTIKALNOG RAZDELJIVAČA ZA ISPITIVANJE HIDRAULIČNIH PRSKALICA

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Sažetak: U Egiptu nije moguće ispitivati vertikalnu raspodelu poljoprivrednih prskalica zbog nedostatka mernih instrumenata kao što su vertikalni razdeljivači. Cilj ovog istraživanja je da razvije i ispita jevtin vertikalni razdeljivač za hidraulične prskalice. Istraživanje je izvedeno u laboratoriji Instiuta za poljoprivrednu tehniku poljoprivrednog fakulteta Univerziteta Kafr El-Sheikh. Vertikalni razdeljivač je napravljen od priručnih materijala u laboratoriji i radionici Univerziteta. Testirana su i ispitivana dva glavna parametra. Prvi ogled bila je ocena tri vertikalne prskalice u laboratorijskim uslovima. Drugi ogled bila je ocena dva različita merna metoda za određivanje efikasnosti prskalice preko CV %. Rezultati su pokazali da su mlaznice Tee-jet XR 110-3 VP dale najveći procenat uhvaćene isprskane tečnosti u poređenju sa mlaznicama Hardi110-02 LS i LU110-04. Razvijeni razdeljivač je uhvatio više tečnosti zbog povećanja radnog pritiska tečnosti u spreju. Vrednost t-testa za LU 110-04 mlaznice bio je -1.48 sa standardnom devijacijom (SE) 0.23, a verovatnoća P-vrednosti 0.89. Može se upotrebiti automatski metod da se oceni CV % i lako se primenjuje. Takođe, nema različitih efekata između ručnog i automatskog metoda zapreminske norme prskanja od 475 $l \cdot ha^{-1}$, 960 $l \cdot ha^{-1}$ i 1150 $l \cdot ha^{-1}$ za određivanje ujednačenosti spreja ili CV %.

Ključne reči: *distribucija u spreju, razdeljivač*

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DEVELOPMENT OF MULTIVARIATE REGRESSION MODEL FOR QUANTIFICATION OF PROXIMATE CONTENT IN *VIGNA RADIATA* USING FOURIER TRANSFORM –NIR SPECTROSCOPY

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Abstract: The Fourier Transform Near Infrared (*FT-NIR*) absorbance spectra (12800-3600 cm^{-1}) of 222 green gram samples was used to build calibration models for the determination of the content of protein, fat and carbohydrate. The samples that comprised the dataset had an average composition of 22.18% of protein, 1.30% fat, and 50.72% carbohydrate. Multivariate regression was used to develop the quantitative models for protein, fat and carbohydrate compounds. The root mean square error of cross validation (*RMSECV*) was 0.191 (R^2 = 91.52) for protein, 0.0271 (R^2 = 88.54) for fat and 0.765 (R^2 = 93.62) for carbohydrate. A fast, simple and accurate method to quantify the proximate content of green gram was developed by using *FT-NIR* spectroscopy. The results showed that *FT-NIR* spectroscopy could support chemical analysis methods.

Key words*: FT-NIR Spectroscopy, green gram, protein, first derivative, calibration*

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INTRODUCTION

Green gram (*Vigna radiata*) is one of the important pulse crops in India. It is a protein rich staple food [1]. It contains about 24 percent protein, which is almost three times that of cereals. It supplies protein requirement of vegetarian population of the country. It is consumed in the form of split pulse as well as whole pulse, which is an essential supplement of cereal based diet. The biological value improves greatly, when wheat or rice is combined with green gram because of the complementary relationship of the essential amino acids. The biochemical composition changes the structure of the grains. It influences the engineering properties of grains reported by [2-4]. Most common methods reported for the determination of protein content are kjeldahl and lowery method. But these methods are tedious, time-consuming, destructive, not economically viable and as they require highly skilled operators.

Fourier transform near-infrared (*FT-NIR*) spectroscopy is an analytical technique that has gained popularity in recent years for analyzing a wide variety of samples used in used in nutritional, pharmaceutical, petrochemical, textile and agricultural industries. The major strength of *FT-NIR* spectroscopy is a rapid technique, nondestructive, accurate and that can be employed as a replacement for time-consuming chemical methods. It is a non-invasive method for the characterization of fat, nitrogen and moisture content in cocoa powder [5] and protein and moisture in fishmeal [6]. Indistinctly, many authors have used different ranges of wavelengths, which extend from the visible spectrum to the NIR in order to estimate multiple properties and they have established different wavelengths ranges. But until now there is not consent between researchers which is the best wavelengths range to study each grain parameters due to different grain nature, type, characteristic and influence of grain grow environments [7]. [5] conclude that the second derivative of *NIR* is the recommended procedure to quantify fat, nitrogen, and moisture content in cocoa powders by infrared spectroscopy and also showed that no single wavelengths were strongly correlated with the protein, fat and carbohydrate content of cocoa powder, which indicates the difficulty of using selected wavelengths or bans to accurately predict the protein, fat and carbohydrate content of the selected product.

On the other hand, India still lags behind the countries with a well-developed of grain sector, especially in processing technology, quality and taste improvement, variety improvement and storage techniques. The grain chemical composition also changes during ozone fumigation [20, 21]. The aim of the present study was to evaluate the potential of *NIR*-Spectroscopy, as a rapid and non-destructive method to predict the protein, fat and carbohydrate content of the green gram. On the other hand, *NIR* models were developed based on partial least square (*PLS*) technique.

MATERIAL AND METHODS

Raw material. Green gram was procured from Department of Pulses, Tamil Nadu Agricultural University, Coimbatore of Tamil Nadu, India and used for the study. The green gram was cleaned manually to remove all foreign materials.

Sample preparation. The initial moisture content of the samples was determined by hot air oven drying at 103 ±2°C for 5 hours [8]. The initial moisture content of green gram was found to be 11.18% (db). In order to maintain the moisture content of green gram for this study, the samples were kept in a refrigerator at 4±2°C. The required quantity of green gram sample was withdrawn and equilibrated at room temperature (29±3°C) before conducting different tests [9].

Protein, Fat and Carbohydrate determination. Protein content was estimated using Kjeldahl method. The fat content of the green gram was estimated by the method described by [10]. Soxhlet extraction with petroleum ether was used for determination of the fat content. The percentage of carbohydrate content in the green gram sample was determined by the method reported by [11].

FT-NIR spectroscopy. The *FT-NIR* spectra were collected on multipurpose analyzer (*MPA*) (Bruker Optics, Ettlingen, Germany) equipped with an integrated Michelson interferometer combined with *OPUS* software (v. 7.2 Bruker Optics, Ettlingen, Germany). It was used for spectral acquisition and instrumental control. For the current study spectra's were recorded in diffuse reflectance mode on the green gram sample with sphere macro sample integrating sphere measurement channel over the range 12800–3600 cm^{-1} at room temperature. For each calibration standard, the spectrum was attained by averaging three spectral scans. Each spectrum was the average spectrum of 64 scans.

Chemometrics. Multivariate analysis was used for quantitative and qualitative analysis. In the present study the in built software (*OPUS*/Quant 7.2) with the instrument was used for multivariate calibration which exclusively uses the PLS algorithm for the calibration and is designed for the quantitative analysis of spectra consisting of bands showing considerable overlap. It correlates more spectral information using larger spectral range with reference value of calibration set. This leads to a higher degree of precision with reduced chance error [12]. Partial Least Square algorithm (PLS), which was proven to be effective in many quantitative applications [13], was used in the present study. The *OPUS* 7.2 software was used for PLS analysis. The samples (222) were divided in the two sets, viz., calibration sample and validation sample set randomly, each set containing 111 samples. The quality of the calibration models for prediction of protein, fat and carbohydrate content was checked by cross validation of the models. It has been reported that the number of samples to develop the calibration model should cover the desired quantification range for the specific analyses, with a minimum of 20–50 samples depending on the complexity of the problem [14].

Data analysis. The spectral data were analyzed using PLS regression with various preprocessing techniques. In this study three spectral preprocessing methods were applied comparatively; it includes first derivative, vector normalization and first derivative plus vector normalization. Vector normalization normalizes a spectrum by first calculating the average intensity value and subsequent subtraction of this value from the spectrum. This method is used to account for different samples thickness [15].

Model accuracy. The performance of final PLS model was evaluated in terms of coefficient of determination (R^2) and root mean square error of cross validation (*RMSECV*). The accuracy of the validation models is obtained according to the highest values of R^2 and *RPD* and lowest *RMSECV*.

$$SSE = \sum \left[\mathrm{Re}\,sidual \right]^2 \qquad (1)$$

where:

Residual [-] - experimental value-Predicted value

The coefficient of determination (R^2) gives the proportion of variability of the property that is described by the model.

$$R^2 = \left(1 - \frac{SSE}{\sum (y_i - y_m)^2}\right) \times 100 \tag{2}$$

where:
$y_i = i^{ih}$ [-] - observation of experimental value,
y_m [-] - mean of the reference results for all samples.

$$RMSECV = \sqrt{\frac{\sum_{i=1}^{n}\left(\bar{y}_i - y_i\right)^2}{n}} \tag{3}$$

where:
n [-] - number of samples in the validation set
y_i , $\bar{y}_i$ [-] - measured and predicted value of the i^{th} observation in the test set.

The number of *PLS* factors included in the model is chosen according to the lowest *RMSECV*.

RESULTS AND DISCUSSION

Distribution of data sets. The 222 samples of green gram that comprised the dataset under study had an average composition of 22.18% of protein, 1.30% of fat and 50.72% of carbohydrate. The protein content in the dataset ranged from 20.5 to 23.4%, the fat from 1.16 to 1.48% and carbohydrate from 45.1 to 55.5%. The samples can be split into three groups according to their protein content. The group with high protein content included 98 samples and had an average protein content of 22.8%, ranging from 22.4 to 23.4%; the intermediate protein content group included 104 samples and had an average protein content of 21.8%, ranging from 21.2 to 22.3% and the group with lower protein content included 20 samples and had an average protein content of 21%, ranging from 20.5 to 21.1%. The uneven distribution of the data leads to better prediction by the model and can be used for wide range of samples [16].

Spectra analyzes. Fig. 1 shows the *FT-NIR* spectra of green gram samples which have major peaks at absorbance units (wave numbers) of 4721.1, 5168.5, 5662.2, 6780.8, 8346.8 and 10028.6 cm^{-1}. The peak and depression in the spectra showed the strong and weak absorbance characteristics of green gram within the region of study. Almost spectra of all samples are parallel (Fig. 1), which means the response of the detector for the sample is linear within the range of study and thus may give better results [17].

Major peaks at wave numbers of 4721.1 and 5168.5 cm^{-1} may be due to the stretching vibrations of *NH* and 2×C=O (esters) bonds of protein. Peaks at 5662.2 and 6780.8 cm^{-1} may be due to first overtone of -CH and $ArNH_2$ bonds of amine (NH_2) groups. Peaks at 8346.8 and 10028.6 cm^{-1} may be due to second overtone of symmetric stretching of $–CH_3$ bonds of methyl groups and second overtone of $ArNH_2$ bonds of amine (NH_2) groups. The vibration of the NH, -CH, $ArNH_2$ and $–CH_3$ molecules are caused by ingredients such as protein, fat and carbohydrate.

The *NIR* region contains several bands that often overlap, making it difficult to extract spectral parameters of the individual bands [13]. Multivariate analysis with partial least square technique has provided a way of overcoming these problems through empirical models. Despite the lack of distinct peaks, it has been shown the PLS can extract relevant information for quantitative determinations [18].

Whole range of wave-number was split a fixed interval to know the group of the most effective wave-number for prediction of protein, fat and carbohydrate. After several pre-processing were choice the best model using each multivariate analysis method (*PLS*), the results to each parameter analyzed are summarized in Tab. 1. In the application of *PLS* algorithm, it is generally known that the spectral pre-processing methods and the number of *PLS* factors are critical parameters [13]. The main advantages of *PLS* is that the resulting spectral vectors are directly related to the constituents of interest; also when analyzing systems that have constituent concentrations that are widely varied and number of samples are not very large *PLS* offers satisfactory results [19]. The performance of the final *PLS* factor was evaluated in terms of correlation coefficient of determination (R), root mean square error of cross-validation (*RMSECV*) and the root mean square error of prediction (*RMSEP*). The optimum number of factors is determined by the highest R^2 and lowest value for *RMSECV* and *RMSEP*.

Fig. 2 (a) and (b) shows the R^2 and *RMSECV* values plotted as a function of *PLS* factors for determining protein, fat and carbohydrate content with first derivative and vector normalization method as the pre-processing technique. Seen from figure, R^2 value increased up to certain limit reached a maximum value and thereafter maintained the value for quantitative model for carbohydrate content but there is no significant change in protein and fat content model. Similarly quantitative model for carbohydrate content the *RMSECV* value decreases sharply with initial factors and maintain the value as *PLS* factor increases.

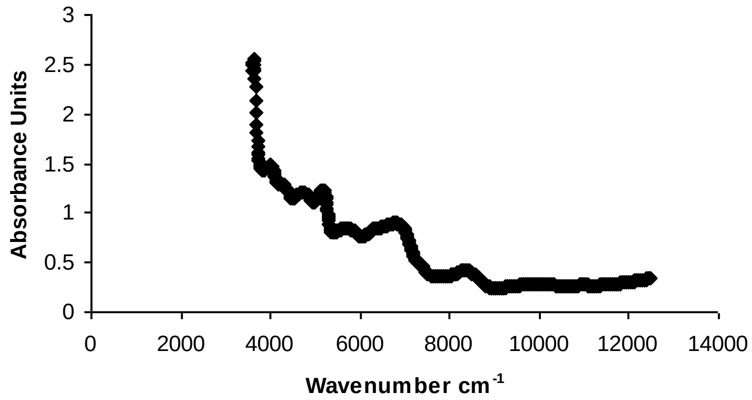
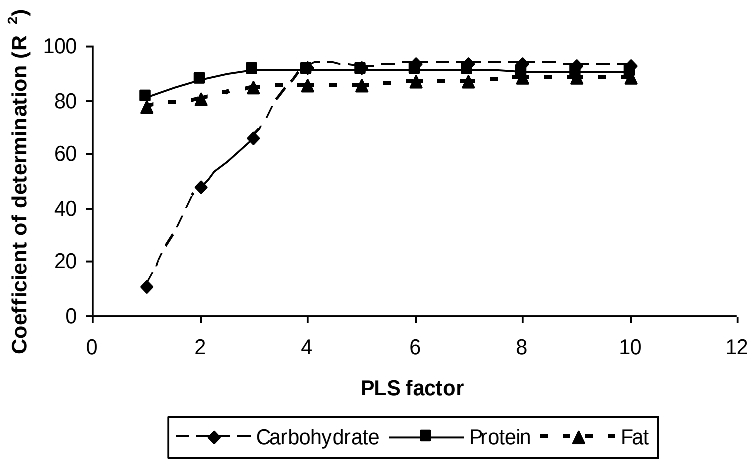


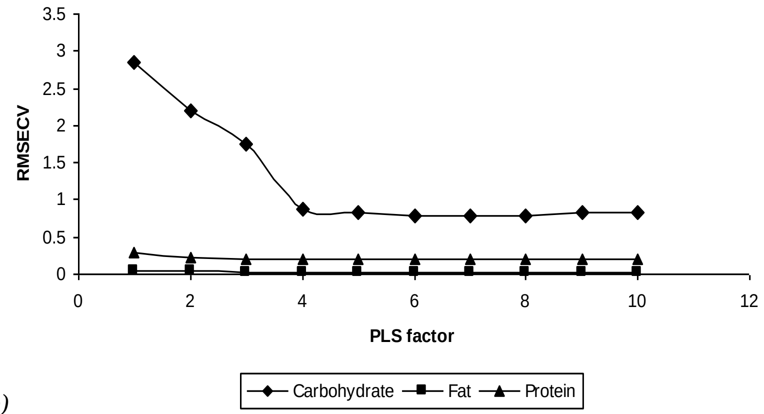
Figure 1. FT-NIR spectra of green gram

The linear regression plot of the validation data sets for the best model showing measured versus predicted protein, fat and carbohydrate content is presented in Fig. 3 (a), (b) and (c) respectively. The equation of the straight line for this cross validation plots of the calibration data sets is represented as $y = 0.9134x + 1.9237$ ($R^2 = 91.08$) for protein, $y = 0.8945x + 0.1373$ ($R^2 = 88.11$) for fat and $y = 0.9366x + 3.2316$ ($R^2 =$

93.18) for carbohydrate showing good performance by this model in predicting protein, fat and carbohydrate content of the green gram samples. The best model was selected based on high value of correlation coefficient and low *RMSECV* values (Tab. 1). The offset and the slope for the equation of the regression line for this set were 1.916 and 0.914, 0.137 and 0.895, 3.234 and 0.937 for protein, fat and carbohydrate respectively. The results of this study clearly demonstrated the efficiency of *FT-NIR* for this application.



(a)



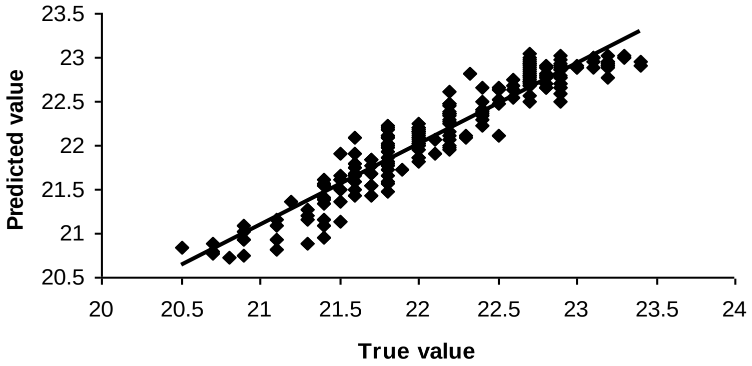
(b)

Figure 2. Effects of number of PLS factors on R^2 (a) and RMSECV (b) for the validation model

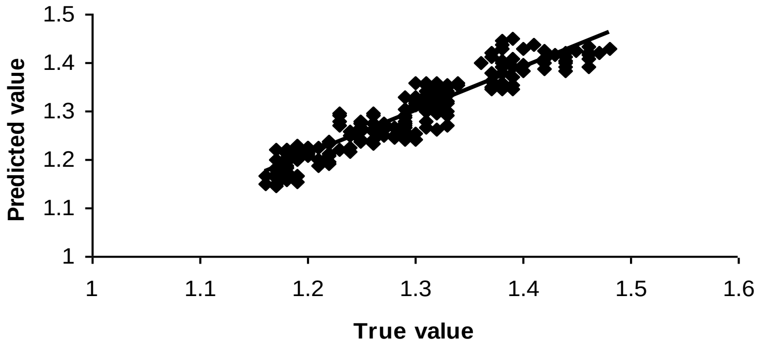
Table 1. R^2, RMSECV and RMSEP values corresponding to PLS factor for determining protein, fat and carbohydrate content with different spectral pre-processing methods

Protein					
Pre-processing technique	*PLS factors*	*R^2 (Validation)*	*RMSECV*	*R^2 (Calibration)*	*RMSEP*
No pre-processing	*7*	*91.24*	*0.350*	*92.34*	*0.185*

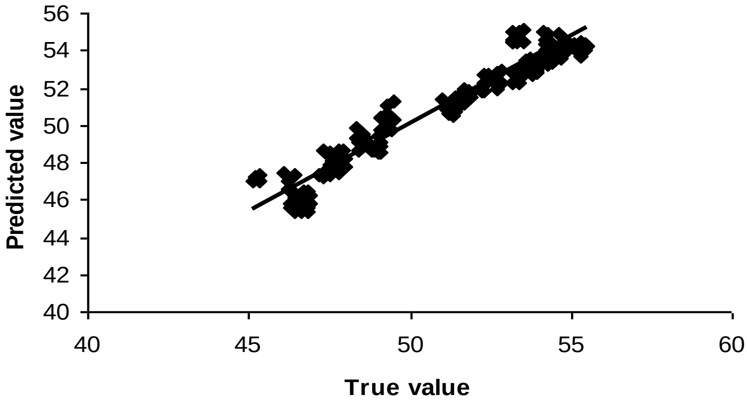
Vector normalization	*3*	*90.54*	*0.202*	*91.21*	*0.196*
First derivative	*5*	*91.52*	*0.191*	*92.46*	*0.183*
First derivative plus Vector normalization	*3*	*91.01*	*0.196*	*91.72*	*0.191*
Fat					
Pre-processing technique	*PLS factors*	*R^2 (Validation)*	*RMSECV*	*R^2 (Calibration)*	*RMSEP*
No pre-processing	*7*	*86.88*	*0.029*	*88.23*	*0.028*
Vector normalization	*8*	*87.85*	*0.0279*	*89.95*	*0.0259*
First derivative	*9*	*88.54*	*0.0271*	*91.06*	*0.0245*
First derivative plus Vector normalization	*8*	*88.09*	*0.0276*	*90.54*	*0.0251*
Carbohydrate					
Pre-processing technique	*PLS factors*	*R^2 (Validation)*	*RMSECV*	*R^2 (Calibration)*	*RMSEP*
No pre-processing	*6*	*93.29*	*0.785*	*94.27*	*0.737*
Vector normalization	*7*	*93.62*	*0.765*	*94.18*	*0.745*
First derivative	*6*	*93.37*	*0.780*	*94.09*	*0.749*
First derivative plus Vector normalization	*5*	*93.47*	*0.774*	*93.96*	*0.755*



(a)



(b)



(c)

Figure 3. Scatter plot of the experimental Vs NIR predicted protein (a), fat (b) and carbohydrate (c) content of the validation data set

CONCLUSIONS

A rapid and simple *FT-NIR* procedure to estimate protein, fat and carbohydrate content in green gram was developed using a calibration model. The model was developed using the spectral region 3600 – 12800 cm^{-1}. Lower values of *RMSECV* and relatively higher values of R^2 showed that *NIR* spectroscopy has potential to predict the quality of green gram nondestructively with almost same accuracy as that of laboratory method. The results presented in this work show that *FT-NIR* can be used as quick, simple, specific and easy automatic tool to predict the content of protein, fat and carbohydrate in green gram samples. It might be an application for green gram quality monitoring in the grain processing industry and various green gram research stations using *FT-NIR* spectroscopy.

BIBLIOGRAPHY

[1] Pandiselvam, R., Thirupathi, V. 2015. Reaction kinetics of Ozone gas in Green gram (Vigna radiate). *Ozone: Science & Engineering*, 37, 1-7.

[2] Ravi, P., Venkatachalam, T. 2014. Important engineering properties of paddy. *Poljoprivredna tehnika*, *39*(4), 73-83.

[3] Pandiselvam, R., Kailappan, R., Pragalyaashree, M. M., Smith, D. 2013. Frictional, Mechanical and Aerodynamic Properties of Onion Seeds. In *International Journal of Engineering Research and Technology (*ESRSA Publications), 2(10), 2647-2657.

[4] Pandiselvam, R., Thirupathi, V., Mohan, S. 2015. Engineering properties of rice. *Poljoprivredna tehnika*, 40(3), pp.69-78.

[5] Vesela, A., Antonio, S., Barrosb, A., Synytsyaa, I., Delgadillob, J., Copikova, M.A., Coimbrab. 2007. Infrared spectroscopy and outer product analysis for quantification of fat, nitrogen, and moisture of cocoa powder, *Analytica chimica acta,* 601, 77–86.

[6] Masoum, S., Alishahi, A., Farahmand, H., shekarchi, M., Prieto, N. 2012. Determination of Protein and Moisture in Fishmeal by Near-Infrared Reflectance Spectroscopy and Multivariate Regression Based on Partial Least Squares, *Iran. J. Chem. Chem. Eng.*, 31(3), 51-59.

[7] Gomez, A.H., He, Y., Pereira, A.G. 2006. Non-destructive measurement of acidity, soluble solids and firmness of Satsuma mandarin using Vis/NIR-spectroscopy techniques. *J. of Food Eng.*, 77, 313–319.

[8] *Official Methods of Analysis*. 2002. Association of Official Analytical Che., Washington DC, USA.

[9] Pandiselvam, R., Pragalyaashree, M.M., Kailappan, R., Thirupathi, V., Krishnakumar, P. 2014. Moisture Dependent Engineering Properties of Onion Seeds, *Journal of Agricultural Engineering,* 51 (2), 36-43.

[10] Cohen, E. H. 1917. Association of Official Analytical Chemists, 54, 212.

[11] Onyeike, E.N., Olungwe, T., Uwakwe, A.A. 1995. Effect of heat treatment and defatting on the proximate composition of some Nigerian local soup thickeners, *Food Che*., 53, 173-175.

[12] Tripathi, S., Patel, K.G., Bafna, A.M. 2010. Nondestructive determination of curcuminoids from turmeric powder using FT-NIR, *J. Food Science Tec.*, 47(6), 678–681.

[13] Sinija, V.R., Mishra, H.N. 2009. FT-NIR spectroscopy for caffeine estimation in instant green tea powder and granules, *LWT - Food Science and Tec.*, 42, 998–1002.

[14] Chen, C., Cai, W., Shao, X. 2007. An Adaptive for selecting representative calibration samples in the continuous wavelet domain for near-infrared spectral analysis, Analytical and Bio analytical Che., 387, 1041–1048.

[15] Ravi, P., Venkatachalam, T., Palanisamy, V. 2014. Fourier transform near-infrared spectroscopy for nondestructive and rapid measurement of moisture content of paddy. *Poljoprivredna tehnika*, *39*(3), 31-40.

[16] Tripathi, S., Mishra, H.N. 2009. Rapid FT-NIR method for estimation of aflatoxin B1 in red chili powder, *Food Control*, 20, 840–846.

[17] Jha, S. N. 2007. Nondestructive Determination of Sweetness of Orange Juice using Portable Near Infrared Spectroscopy, *J. of Agricultural Eng*., 44(3), 10-14.

[18] Mcshane, M. J., Cote, G. L. 1998. Near-infrared spectroscopy for determination of glucose lactate, and ammonia in cell culture media, *Applied Spectroscopy,* 52, 1073–1078.

[19] Cramer, R. D. 1993. Partial least squares (PLS): Its strengths and limitations", *Perspectives in Drug Discovery and Design*, 1(2), 269–278.

[20] Ravi, P., Venkatachalam, T., Rajamani, M. 2015. *Decay Rate Kinetics of Ozone Gas in Rice Grains*. Ozone: Science & Engineering, 37(5), pp.450-455.

[21] Pandiselvam, R., Thirupathi, V., Anandakumar, S. 2015. Reaction Kinetics of Ozone Gas in Paddy Grains. *Journal of Food Process Engineering*, 38(6), pp.594-600.

RAZVOJ MULTIVARIJANTNOG MODELA REGRESIJE ZA APROKSIMATIVNU PROCENU SADRŽAJA *VIGNA RADIATA* KORIŠĆENJEM FURIJEOVE TRANSFORMACIJE – NIR SPEKTROSKOPIJE

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Sažetak: Furijeova transformacija blizu infracrvenog (*FT-NIR*) absorbovanog spektra (12800-3600 cm^{-1}) kod 222 uzorka zelenog pasulja korišćena je da se izrade kalibracioni modeli za određivanje sadržaja proteina, masti i ugljenih hidrata. Uzorci koji su činili skup podataka imali su srednji sadržaj od 22.18% proteina, 1.30% masti i 50.72% ugljenih hidrata. Multivarijantnom regresijom su razvijeni kvantitativni modeli proteina, masti i ugljenih hidrata. Srednje kvadratno odstupanje unakrsne procene (*RMSECV*) bilo je 0.191 (R^2 = 91.52) za proteine, 0.0271 (R^2 = 88.54) za masti i 0.765 (R^2 = 93.62) za ugljene hidrate. Tako je razvijen brz, jednostavan i precizan metod za kvantitativnu procenu sastava zelenog pasulja upotrebom *FT-NIR* spektroskopiju. Rezultati su pokazali da *FT-NIR* spektroskopija može da podrži metode hemijske analize.

Ključne reči: *FT-NIR spektroskopija, zeleno zrno, protein, pasulj, prvi derivat, kalibracija*

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Original scientific paper

DESIGN AND DEVELOPMENT OF PULVERIZING ATTACHMENT TO CULTIVATOR

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Abstract: In tillage, active and passive tillage tools used in India faces problem like, poor soil-tire interface, clod formation, compaction due to heavy traffic and timeliness in operation. Hence, it was planned to fabricate a pulverizing attachment to cultivator and to study its performance. Major components of machine developed are frame, cultivator tines, pulverizing roller attachment, power transmission system and protecting cover. A frame is for holding different components. Cultivator tines were hold with help of adjustable clamps which are mounted on frame. Behind cultivator tine *PTO* operated pulverizing roller was attached which is operated at 225 min^{-1}. The average field efficiency, fuel consumption and cost of operation was 78.89%, 12.94 $l \cdot ha^{-1}$ and 2157.42 $Rs \cdot ha^{-1}$ respectively.

Key words: *combination tillage tool, performance, active-passive tillage tool, design*

INTRODUCTION

Tillage is the mechanical manipulation of the soil and plant residue to prepare a seedbed where seeds are planted to produce grain for our consumption. Also tillage breaks soil, enhances the release of soil nutrients for crop growth, destroys weeds and enhances the circulation of water and air within the soil [6]. Nearly all tillage tools utilize passive tillage elements in India. A draft force is applied to the tool, which causes the elements to move through the soil. The power required is developed by the tractor engine and is transmitted through the soil-tire interface and the tractor drawbar. Because of the poor efficiency of power transmission at the soil-tire interface, tillage energy

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efficiencies are low. Also, because tractors require considerable weight to provide necessary traction, soil compaction may occur and increased power is required to overcome the wheel slip and rolling resistance of the tractor tires. According to the previous researches, about 60% of total energy required for preparing the soil is used for tillage and preparing a good seedbed. In addition, the high cost of energy, makes the farmers to find alternative economic tillage methods [1].

There is way to bypass the inefficient soil-tire interface is through active powered tillage elements. These active elements are usually powered by the tractor *PTO* drive. Due to repeated use of primary, secondary and active tillage implements soil layers become compacted. Machines for tillage operation usually pass the farm four times or more which causes soil compaction, increases cost of labor and energy [2]. Tillage implements works on the basis of two working motion sliding type and rotating type. The implements like M.B. plough, cultivator cut the soil by sliding action. Disc plough, disc harrow, rotavator, clod crusher or roller cut and pulverize the soil by working in rotary action. Clod formation subsequent to ploughing or disking is a major problem in arid and semi-arid zones of India. Clods create obstruction to penetration of furrow openers of seed drill and do not allow intimate contact between seeds and soil. Pulverization of clods is necessary to avoid the above problems.

However, the combination of implements that enables the task to be completed in the shortest time with minimum operating cost and energy requirement is usually selected. Among these types of implements, sliding type implements consume more draft than rotating type implements due to soil frictional force and contact area of implement. While the rotary type of implements produce negative draft. That's why the idea behind the combining these sliding and rotary type implements saves more power, time, cost very efficiently.

A few researchers have also conducted studies on development and performance evaluation of *2WD* tractor drawn active–passive combination tillage implements have also been conducted in India and confirmed the same results as obtained in western countries. The combination tillage tool mounted on a tractor does the primary and secondary tillage operations simultaneously in a single pass and added that combination tillage tool reduced bigger size clods in the soil and improves aeration and moisture holding capacity and medium uniformity of soil and finer pulverization modulus obtained by using combination tillage. And also added that maximum loosening of the soil was obtained by the combination tool as reflected by the low soil bulk density range of 1.15±0.05 $g \cdot cm^{-3}$ as against the normal 1.4±0.20 $g \cdot cm^{-3}$ encountered in the conventional implements operated field. Savings of 44 to 55 per cent in cost and 50 to 55% in time are possible by the use of combination tillage tool for seed bed preparation [4]. Using cultivator with spiked tooth roller the soil parameters measured in the range of 12 to14 mm, 1.21 to 1.36 g/cc and 0.568 to 1.5 $kg \cdot cm^{-2}$ in case of clod *MWD*, dry bulk density, and clod index of soil respectively [5].

MATERIAL AND METHODS

Conceptual design of pulverizing attachment to cultivator. A pulverizing attachment to cultivator was designed and developed to combine primary and secondary tillage operations in single pass to ensure timeliness in seed bed preparation. The pulverizing attachment to cultivator consist of a frame with cultivator tines, pulverizing attachment having helical blade, power transmission system to provides power to pulverizing attachment, framework to mount roller and three-point linkage unit. The working principle behind the pulverizing attachment to cultivator which is having pulverizing roller as active unit behind implement and in front cultivator tines are attached as passive unit. Cultivator tines open furrow and in the rear PTO operated roller cut and pulverize the soil at optimum condition for tillage.

Design considerations: The components of pulverizing attachment to cultivator were designed and fabricated based on the parameters like functional requirements, engineering and general considerations. The assumptions made in the design of pulverizing attachment to cultivator are as follow [3]:

1. No draft was included for pulverizing attachment because it is rotating unit and has negative draft.
2. Speed of Power Take Off shaft was taken as 540±10 min^{-1}.
3. Average speed of operation of tractor in the field was kept as 3 $km \cdot h^{-1}$.
4. Maximum soil resistance was considered as 0.75 $kg \cdot cm^{-2}$.
5. A seven tine cultivator having spacing 20 cm and working depth 15 cm was considered.
6. Coefficient of friction in un-ploughed soil was taken 0.85.

Assessment of draft and power requirement. The draft requirement of the tractor operated pulverizing attachment to cultivator would be estimated using factors related to implement and the type of soil. The specific soil resistance of medium black soil of the area was considered as 0.75 $kg \cdot cm^{-2}$.

Total working width of cultivator = No. of tine × tine spacing = 7 × 20 = 140cm = 1.4m
Cross section area of 7 furrows = 140 × 15 = 2100 cm^2
Maximum draft = 2100 × 0.75 = 1575 kg
Speed of travel = 3 $km \cdot h^{-1}$ = 3000 $m \cdot h^{-1}$ =0.833 $m \cdot s^{-1}$

The power required for the designed draft was estimated using following formula.

$$P = \frac{D \times S}{1000} \quad (1)$$

where:
P [kW] - power required,
D [N] - maximum draft,
S [$m \cdot s^{-1}$] - forward speed.

P = (1575 × 9.8 × 0.833)/1000 = 12.857 kW = 17.24 HP

Horse power required to operate the implement in un-ploughed soil;
= (Total power required)/ (Coefficient of friction) (2)
= 17.24/0.85 = 20.28 HP

Hence, this implement can easily be hitched and operated by most of the Indian makes tractors of 35 HP capacity.

Design of functional components of pulverizing attachment to cultivator. The detailed design of the functional components and different mechanisms were carried out. The machine consists of frame, cultivator tines, pulverizing roller and power transmission system. The design of (1) Helical blade of pulverizing roller (2) Bevel gear mechanism (3) Chain sprocket mechanism was taken up:

1. Design of helical blade: The pulverizing members which are helical blades were fabricated similarly to lawn mower blades and are inserted in disc at 900 with tangent in such a way that it forms helical shape and progressively come in contact with soil. Five numbers of helical blades were fabricated and designed as follows [3].

Total area of helical blade striking on soil = Inclined length × thickness

$= 135\ cm \times 0.5\ cm = 67.5\ cm^2$

The maximum soil resistance $= 67.5 cm^2 \times 0.75\ kg/cm^2 = 50.625\ kg$

Maximum bending moment in the blade,

M_b *= Soil resistance × radial distance* $= 50.625\ kg \times 22.5\ cm = 1139.0625\ kg\text{-}cm$

Maximum bending stress for mild steel is 700 MPa. Calculating actual bending stress as per following formula [3].

$$\sigma_b = \left(\frac{M_b \times y}{I}\right) \tag{3}$$

$$700 = (1139.0625 \times 12 \times w \times 2) / (2 \times 0.5 \times w^3)$$

$$W = 6.395\ cm \approx 64\ mm$$

Hence design is safe. Selecting 75 mm width and 1350 mm length and 5 mm thick for helical blade.

2. Bevel gear mechanism: The power was transmitted to shaft through bevel gear mechanism. The size selection of bevel gear was carried out using standard formula.

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} \tag{4}$$

where:

N_1 [min^{-1}] - No. of revolution of driving wheel (540),
N_2 [min^{-1}] - No. of revolution of driven wheel,
T_1 [-] - No. of teeth on driving sprocket (10),
T_2 [-] - No. of teeth on driven Sprocket (18).

Substituting the values as above the number of revolution of driven wheel comes out as:

$$N_2 = 540 \times 10/18 = 300\ min^{-1}$$

To get required number of min^{-1} standard bevel gears of 10 and 18 teeth were used.

3. Chain and sprocket mechanism: The power was transmitted to shafts of pulverizing roller through chain and sprocket mechanism. The selection of size was carried out using standard formula. Dimension of the chain i.e. thickness, width and length of chain were 25, 38.1 and 3500 mm respectively.

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} \tag{5}$$

$$N_2 = (300x15)/20 \text{ so, } N_2 = 225\ min^{-1}$$

Standard sprockets of 15 and 20 teeth were used.

Fabrication of pulverizing attachment to cultivator. Ease of assembling and dismantling for repairs and inspection were duly considered. Major components of machine developed are as follow:

- *Frame:* The frame is meant for holding different components of pulverizing attachment to cultivator. It is subjected to bending, tension, and vibrations. The frame was fabricated using double L section having size 65 mm × 65 mm × 6 mm for accommodating cultivator tines as well as power transmission system and cultivator tines. The three point hitch was fabricated using 75 mm × 5 mm flat as describe in Fig. 1.

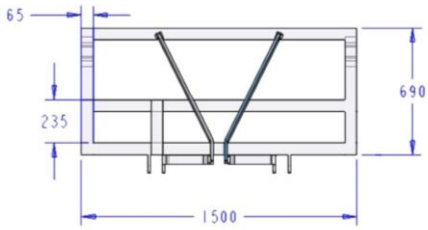
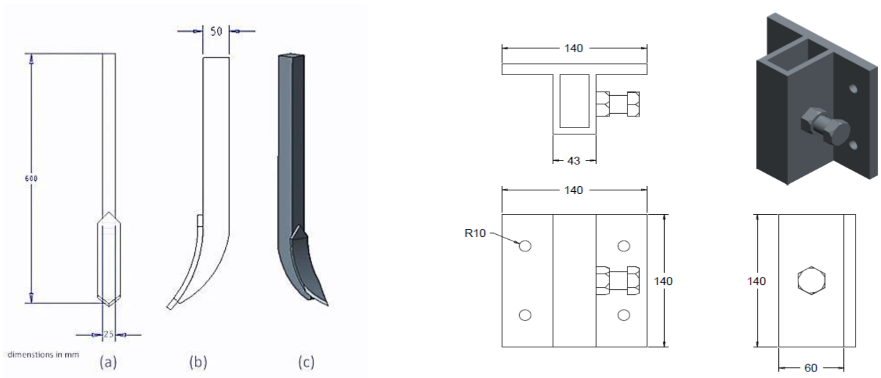


Figure 1. Detailed drawing of frame (top view)

- *Cultivator tines:* Cultivator is much popular implement used as primary as well as secondary tillage operation and it requires relatively less power per meter of width in these conditions. It is essential that this operation should be performed at the appropriate moisture content. Since the basic objective is to achieve good tilt, cultivation should be done when the soil is in the most workable conditions. Standard heavy duty reversible shovel type tines used with adjustable clamps so tines can be moved vertically and horizontally. Drawing of cultivator tine and adjustable clamps are in Figs. 2(A) and 2(B).



a. *b.*

Figure 2. a. Detailed drawing of cultivator tine; (a) front view (b) side view (c) perspective view
b. Detailed drawing of adjustable clamp plate

- *Pulverizing roller:* Pulverizing roller attachment to cultivator with helical blades pulverizes the soil to a greater degree. Tractor-drawn pulverizing roller attachment for cultivator was mounted at the back of the cultivator. The pulverizing roller consists of disc, central shaft, pulverizing members and mounting link. The pulverizing roller was designed for cutting, mixing, and clod breaking which ultimately pulverizes the soil by impact force. The cutting and clod breaking action of this unit provides excellent land preparation.

The incorporation is done by pulverizing blade welded over no. of discs which are mounted on the single horizontal shaft operated by *PTO* power. The pulverizing blade run in helix pattern from one disc to another in such a way that not more than one portion of a particular blade is in contact with ground at a time. Hence medium speed was usually selected as it is adequate for both the wet or dry soil conditions. Based on review collected, speed of the roller was selected as 225 min^{-1}. Design of pulverizing roller is shown in Fig. 3.

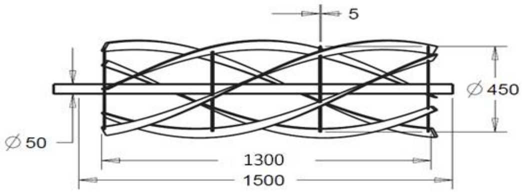


Figure 3. Detailed front view drawing of pulverizing roller

- *Power transmission system:* Power transmitted from *PTO* to Hub which is having 1: 1.8 bevel gear ratio. So that shaft-I transmits 540 min^{-1} to shaft-II at 300 min^{-1}. Shaft-II is connected to chain and sprocket transmission system which transmits 225 min^{-1} at 1:1.33 velocity ratios of sprockets. Following are design specifications of whole power transmission unit. As a general principle fine tilts are produced by a combination of slow tractor speeds, fast rotor speeds. Schematic diagram of power transmission is shown in Fig. 4.

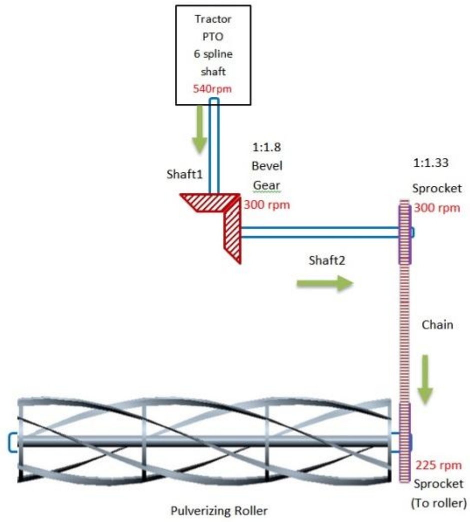


Figure 4. Schematic diagram of power transmission system

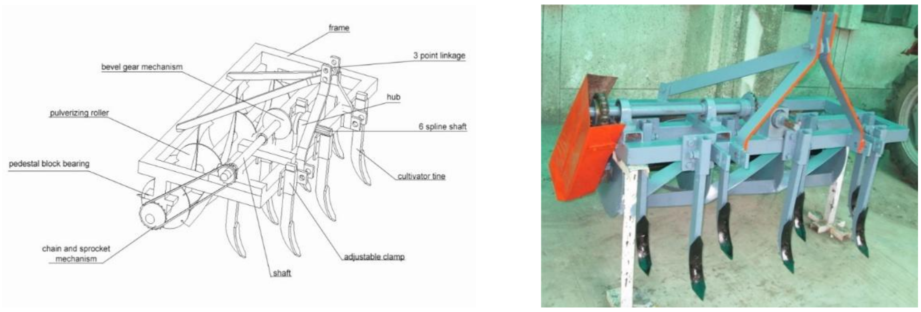
Experimental procedure: As such there was no standard test code for rotary implement testing i.e. rotavator and developed pulverizing attachment to cultivator which is having pulverizing roller, all laboratory and field tests were carried out indirectly as per the recommendation of the Regional Network for Agricultural Machinery (*RNAM*, 1983) and other related test code.

The instruments and equipment used for the field test were tractor, measuring tape, developed pulverizing attachment to cultivator, digital dynamometer, stop watch, etc.

Before conducting the actual field test, necessary settings and proper attachments were made and preliminary tests were conducted. Marking of the test field was done with white powder as per layout. Tractor drive wheel was marked with coloured tapes for easy counting of number of revolutions during slip measurement and tractor was operated in B1 gear setting for controlling forward speed between 2.4 to 3 km/h. The performance parameters depth of cut, fuel consumption, draft, field capacity and slip were determined. The other details of experimental fields are given in Tab. 1.

Table 1. Details of experimental field

Parameters	***Field***
Type of soil	*Medium black*
Previously grown crop	*Sorghum*
Moisture content [%]	*12.57*
Bulk density [$g \cdot cm^{-3}$]	*1.6*
Cone Index [kPa]	*738.74*



a. *b.*

Figure 5. a. Detailed drawing of pulverizing attachment to cultivator,
b. Developed pulverizing attachment to cultivator

RESULTS AND DISCUSSION

While designing and development of the tractor operated pulverizing attachment to cultivator, the basic emphasis was given on simplicity of fabrication, use of locally available material and minimum cost of fabrication. Anticipated view of developed pulverizing attachment to cultivator shown in Fig. 5(b) and its specifications with all units is shown in Tab. 2. Results obtained during the field performance of the developed pulverizing attachment to cultivator are shown below performance parameters like draft, wheel slip, fuel consumption and field efficiency are discussed.

Table 2. Detailed specifications of pulverizing attachment to cultivator

Sr.	*Particulars*	*Specifications*
1	*Name of implement*	*Pulverizing attachment to cultivator*
2	*Type of hitch and its detail*	
	Linkage	*3 – Point*

	Power source	*Tractor PTO (John Deere - 5310)*
3	*Overall Dimensions*	
	Length, mm	*1500*
	Width, mm	*680*
	Height, mm	*1050*
	Weight, kg	*260*
4	*Frame*	
	Material of fabrication	*Mild Steel (L – channel size: 65 mm × 65 mm × 6 mm)* *Three point hitch (75mm × 5mm)*
	Length, mm	*1500*
	Width, mm	*690*
	Height, mm	*850*
5	*Cultivator Tine*	
	Material of fabrication	*Mild Steel*
	Nos. of tine	*7 with reversible type shovel*
	Height, mm	*600*
	Width, mm	*25*
	Thickness, mm	*55*
	Spacing between tines, mm	*210*
6	*Pulverizing Roller*	
	Material of fabrication	*Mild Steel*
	Length, mm	*1300*
	Nos. of dics	*4*
	Nos. of helical blade	*5*
	Dia. of disc, mm	*450*
	Method of fixing	*Pedestal roller bearing (Nos. 2)*
	Width of helical blade, mm	*75*
	Length of helical blade, mm	*1350*
	Thickness of helical blade, mm	*5*
7	*Power transmitting shaft*	
	Material of fabrication	*Mild steel rod*
	Length, mm	*750*
	Diameter, mm	*60*
8	*Chain and sprocket mechanism*	
	Type	*Pintle chain*
	Width, mm	*25*
	Length, mm	*3500*
	Thickness, mm	*15*
	Pitch, mm	*30*
	Velocity ratio	*1 : 1.33*
9	*Bevel gear*	
	Material of fabrication	*Cast iron*
	Velocity ratio	*1:1.88*
10	*Pedestal block bearing*	
	Material of fabrication	*Casting with press fitted bearing*
	Diameter, mm	*(1) 40 (2) 50*
	Length, mm	*265*
	Height, mm	*152*

Overall dimensions of developed pulverizing attachment to cultivator are 1500 mm length, 680 mm width and 1050 mm height. Developed pulverizing attachment was test in field and following performance parameters were obtained. Average depth of cut 16.92 cm for pulverizing attachment to cultivator was observed. Pulverizing attachment to cultivator worked at higher working depth of operation. The effect of wheel slip during operation of developed pulverizing attachment to cultivator was recorded The wheel slip was recorded 4.01% for pulverizing attachment to cultivator which is less due to active and passive units operate simultaneously. Draft was also determined and the value of draft 1423.86 N for pulverizing attachment to cultivator was recorded. Pulverizing attachment to cultivator having lower draft because the *PTO* operated pulverizing roller actually pushed tractor in direction of travel. Field efficiency was determined by standard procedure during tillage operation. The mean value of field efficiency was calculated 78.89% for pulverizing attachment to cultivator. Fuel consumption was determined by standard procedure. Quantity of fuel during the operation of pulverizing attachment to cultivator was recorded 12.94 $l \cdot ha^{-1}$.

CONCLUSIONS

The developed pulverizing attachment to cultivator has worked satisfactorily in the field. The average field efficiency, fuel consumption and cost of operation was 78.89%, 12.94 $l \cdot ha^{-1}$ and 2157.42 $Rs \cdot ha^{-1}$ respectively. The developed pulverizing attachment to cultivator was found effective in the Saurastra region of Gujarat. The performance evaluation of pulverizing attachment to cultivator was satisfactory for working in the well prepared seed bed. A medium size of tractor can meet the draft. The reduced wheel slip and draft was found. The field efficiency was found satisfactory and fuel consumption was significantly reduced compared to other tillage implement.

BIBLIOGRAPHY

[1] Bayhan, Y., Kayisoglu, B., Gonulol, E., Yalcin, H., Sungur, N. 2006. Possibilities of direct drilling and reduced tillage in second crop silage corn. *Soil and tillage research*, 88(1-2), 1-7.

[2] Hashemi A., Ahmad, D., Othman, J., Sulaiman, S. 2012. Development and Testing of a New Tillage Apparatus. *Journal of Agricultural Science*.Vol. 4(7), 103-110.

[3] Kailappan, R., Manian, R., Amuthan, G., Vijayaraghavan, N.C., Duraisamy, G. 2001a. Combination tillage tool. I. (Design and development of a combination tillage tool) *Agric. Mechan. Asia, Africa, Latin America.* 32 (3): 19–22.

[4] Kailappan, R., Swaminathan, H.R., Vijayaraghavan, N.C., Amuthan, G., 2001b. Combination tillage tool. II. (Performance evaluation of the combination tillage tool). *Agric. Mechan. Asia, Africa, Latin America.* 32 (3): 19–22.

[5] Maheshwari, T. K., Thakur, T. C., Varshney, B. P. 2005. Spiked clod crusher and planker performance under different soil conditions. *Agricultural Engineering Today*. Vol. 29(3-4): 6-11.

[6] Reicosky, D.C., Allmaras, R.R. 2003. Advances in tillage research in North American cropping systems. *Journal of Crop Production*. 8(1): 75-125.

KONSTRUKCIJA I RAZVOJ PRIKLJUČKA ZA USITNJAVANJE NA KULTIVATORU

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Sažetak: Pri obradi zemljišta aktivnim i pasivnim oruđima u Indiji postoje problemi kao što su: slabo trenje podloge i pneumatika, formiranje grudvi, sabijanje zbog kretanja teških mašina i trajanja operacija. Zato je planirana izrada prikjučka za usitnjavanje na kultivatoru i ispitivanje njegovih performansi. Glavne komponente mašine su ram, kultivatorki prsti, valjak za usitnjavanje, sistem prenosa pogona i zaštitna hauba. Ram nosi sve delove. Prsti su pričvršćeni podesivim sponama na ramu. Iza prstiju je postavljen valjak za usitnjavanje sa pogonom od *PV*, koji rotira brzinom od 225 min^{-1}. Srednja efikasnost, potrošnja goriva i troškovi rada su iznosili: 78.89%, 12.94 $l \cdot ha^{-1}$ i 2157.42 $Rs \cdot ha^{-1}$, redom.

Ključne reči*: oruđe za kombinovanu obradu, performanse, oruđe za aktivnu-pasivnu obradu, konstrukcija*

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IRRIGATION MANAGEMENT FOR NON-MONSOON CROPS IN A MAJOR CANAL COMMAND IN EASTERN INDIA UNDER WATER LIMITING ENVIRONMENT

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Abstract: Acute irrigation water deficit during the non-monsoon (*rabi*) season in the Hirakud canal command in Eastern India demands efficient irrigation management strategies (*IMS*s) to sustain the irrigated agriculture. The study was undertaken to analyse the impact of different *IMS*s – namely full and deficit irrigation, on water use efficiency of different *rabi* crops and evolve the most efficient *IMS*s. Various water balance parameters were estimated on daily basis and stage wise crop production function was applied to compute the actual crop yields of five major *rabi* crops. The best *IMS*s for wheat, maize, rice, green gram and mustard were found to be 30% deficit irrigation at 14 days interval, 30% deficit irrigation at 7 days interval, 20% deficit irrigation at 4 days interval, 60 mm of irrigation per application at 21 days interval, and 20% deficit irrigation at 7 days interval, respectively. Realizing the scarce water resources and ever rising population, it is highly essential to implement the generated IMSs with a view to bring more area under cultivation and enhance the production potential of the command area.

Key words*: deficit irrigation, fixed depth application, soil moisture balance, water use efficiency*

INTRODUCTION

Rapid environmental alteration has adversely affected the agriculture sector [16] owing to limited water availability. Irrigated agriculture is the largest water user at global level, which consumes nearly 80% of the world's developed water resources [27]. On the other hand, ever-increasing urban and industrial sectors place greater pressures

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on agricultural water use. Hence, its effective management through improved irrigation management practices is of topmost importance to the agricultural scientists and researchers. It has been proven that almost 50% potential water saving can be resulted from better irrigation management practices [22].

Agricultural water management needs proper understanding of the crop irrigation scheduling. If water supply is adequate, irrigation can be given at times, to bring the root zone soil moisture to field capacity. However, deficit irrigation (DI) practices need to be followed under water limiting conditions, realizing the critical growth stages of crops. Deficit irrigation practices differ from traditional water supplying practices, on the way of scientifically under-irrigating crops in a controlled way [25,10]. Though under-irrigation results in stress and subsequent reduction in crop yield, still it has greater potential for increasing the water use efficiency (*WUE*) under water scarce environment [13] as the saved water can be diverted to irrigate other crops, for which amount of water would normally be insufficient under traditional irrigation practices. Deficit irrigation strategy in many crops has frequently proved to be an efficient tool to enhance *WUE* [20,12,9,24].

Similarly, in a field experiment with different levels of *DI* it was observed that 30% *DI* to sweet corn could be a water-saving treatment without a significant decrease in yield. In addition, highest protein content and sugar amount was also observed at the same *DI* level [11]. In another field experiment on two genotypes of maize it was found that the water deficit stress significantly increased glucose, fructose, and sucrose contents. The highest *WUE* was found at 50% *DI* [2]. Deficit irrigation can also be used as a cost-effective tool for attaining water for environmental purposes. Application of non-linear optimization model on *DI* involving crop production and profit functions achieved environmental flows and maximized net returns [18]. Simulation of an onion crop under optimized regulated *DI* conditions increased the crop yield by 3–7%, where as the gross margin raised up to 30% compared with an irrigation strategy, where the stress levels remain constant during the whole growth cycle [6]. Application of *DI* strategies on tomato crop allowed up to 48% of water saving and improved quality of fruits under a semi-arid climate in south Italy [19].

Previous studies have indicated that water-saving irrigation not only contributes to water saving but also to the reduction of greenhouse gas emissions, which can alleviate the negative impact of climate change on agricultural production [28,17]. Growing rice under *DI* in arsenic contaminated areas of West Bengal, India reduced the arsenic load. Crop water productivity was also reported to be increased by 11% under *DI* [21]. Now-a-days, use of saline water for irrigation and practicing DI are among the most frequently used methods for overcoming water shortages. However, since both salinity and drought reduce the availability of soil water for crops, yield reduction needs to be predicted accurately [5]. Therefore, before implementing a *DI* program it is imperative to know the crop yield response to water stress, either during defined growth stages or throughout the growing season.

The canal command of the Hirakud irrigation project, Odisha (eastern India) is one of the major surface irrigation projects and is highly heterogeneous in nature. Hence, irrigation management in such a case is a very complex process. Spatio-temporal variation in water supply has resulted in much lower crop yield as compared to the national average. Rice being the major crop in all the seasons, its diversification to non-rice crops (vz. wheat, maize, pulses, oilseeds, vegetables etc.), specifically during *rabi* season has, therefore, become necessary for optimal utilization of land and water resources of the command area. It is also inevitable to adopt alternate irrigation management strategies. In this study, a regional daily soil moisture balance model was developed for estimation of crop yield and water requirement with a view to evaluate the net benefit per unit area of each crop under different irrigation management strategies.

MATERIAL AND METHODS

Area description. The Hirakud canal command area lies between latitude 20°53’ to 21°36’ N and longitude 83°25’ to 84°10’ E covering an area of about 2,540 km^2 (Fig. 1). Topography of the area varies from plain to undulating and comprises mostly terrace lands with average slopes between 1 to 6%. The elevation of the land surface varies from 120 to 180 m above the mean sea level. The soils of the study area have been developed mostly from granite rocks. The command area is characterized by sub-humid climate with extremely hot summer, cold winter and uneven distribution of rainfall. During summer (March-May), day temperature varies from 35 to 45°C and May is the hottest month of the year. In winter (November-February), temperature varies from 10 to 20°C and December is the coldest month of the year. The relative humidity is high (more than 75%) during monsoon (mid June-mid October) and it is rather low (30 to 40%) in summer. The average annual rainfall of the command is around 1200 mm, out of which about 90% is received during monsoon. The southwest monsoon is the principal source of rainfall.

The study region prevails two principal crop seasons, viz. *kharif* (June to October) and *rabi* (November to May). Rice is the major crop in both the seasons. It is cultivated in more than 90% of the culturable command area (*CCA*) during monsoon and during non-monsoon season rice area exceeds 40% of *CCA* (1,590 km^2). Other crops like wheat, sugarcane, pulses, millets, oilseeds, vegetables, and condiments etc. are also cultivated in the command area in both the crop seasons.

Irrigation strategies. The applied depth of irrigation may vary between different crops grown on different types of soils and climatic zones. However, this heterogeneity is often not considered and allocation plans are based on a fixed depth of water. When water is scarce, using *DI* may be beneficial compared to full irrigation [14]. As the degree of deficit for different crops during different growing periods are different, DI results in variable depth of irrigation. Based on these findings, the following three *IMS*s were considered for obtaining the irrigation management plans. The heterogeneity in the irrigation scheme in terms of soil, crop, system efficiency, irrigation interval and other parameters influencing the water demand is not considered in this strategy.

(1) Full irrigation strategy: Full irrigation is the depth of application needed at the time of irrigation to bring the root zone soil moisture to field capacity. When the irrigation interval is large, full irrigation may still cause stress to the crop and reduce the crop yield. Crop yields were estimated for different irrigation intervals with full irrigation at each event.

(2) Fixed depth irrigation strategy: Fixed depth irrigation is the application of a fixed quantity of water to a crop per irrigation. In this strategy, three different fixed depths (6, 8 and 10 cm) for non-rice crops and three different fixed depths (9, 12 and 15 cm) for rice crop were considered. The effects of those different fixed depths along with different irrigation intervals (7, 14, 21 and 28 days for non-rice crops and 4, 8 and 12 days for rice) on crop yield and *WUE* were studied by using the concept of daily soil

moisture balance. *WUE* has been defined as crop yields per unit amount of irrigation water applied ($kg \cdot ha^{-1}$-mm).

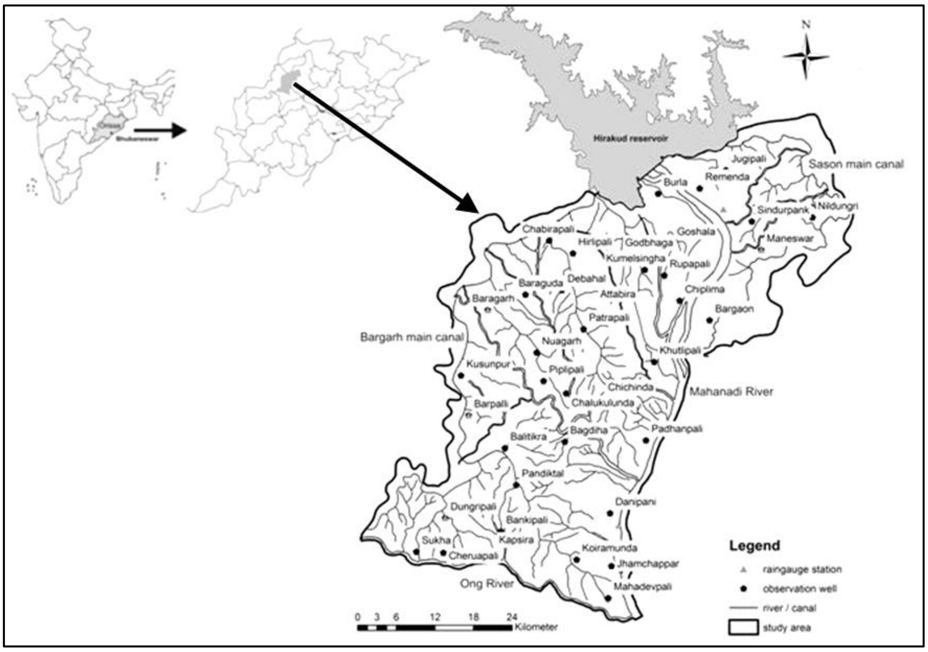

Figure 1. Location map of the study area

(3) Deficit irrigation strategy: In a water-limiting situation, it may be beneficial to apply less amount of water per application than the full irrigation, which is termed as deficit irrigation that helps in spreading the water to a larger area. The deficit ratio is used to represent the degree of deficit that ranges from zero (applying no irrigation water or skipping this irrigation) to one (full irrigation). The intermediate values of deficit ratios (0.1 to 0.9 with an increment of 0.1) indicate the irrigation depth as a fraction of the full irrigation. Effect of those different deficit ratios along with different irrigation intervals on the crop yield and *WUE* irrigation was studied by the help of daily soil moisture balance model.

Soil moisture balance model. A soil moisture balance model was formulated in order to estimate the yield and water requirement of different *rabi* crops grown in the canal command under different *IMS*s. Various model components were estimated on daily basis and actual crop yields were estimated by using the dated crop production function that consider the water stress and yield sensitivity factors during each crop growth stage. Java language was used to formulate the soil moisture balance model. Considering the effective root zone of crops as single layer and neglecting the capillary contribution from groundwater, the generalized soil moisture balance model for crops can be written as:

$$SMC_{t+1}Z_{t+1} = SMC_tZ_t - ETa_t - SP_t + Da_t + ER_t + SS_t + PS \quad (1)$$

where:

SMC $[cm \cdot m^{-1}]$ - soil moisture content,

Eta [cm] - actual evapotranspiration on t^{th} day,
Da [cm] - depth of irrigation applied,
SP [cm] - seepage and deep percolation,
ER [cm] - effective rainfall,
Z [m] - root zone depth,
SS [cm] - surface storage or ponding depth,
PS [cm] - pre-sowing irrigation,
t [days] - time index.

During *rabi* season, the water requirement for nursery raising and transplanting of rice was taken as 250 mm and for non-rice crops, a pre-sowing irrigation of 40 mm was considered for land preparation [23].

In the soil moisture balance model, the effective root zone of rice (45 cm) and the ponding depth was together considered as a single layered reservoir. A ponding depth of 5 cm was allowed throughout the growing period, except last 15 days before harvesting [26]. Seepage and percolation loss components were together considered as 6 mm/day [4]. For non-rice crops, seepage and percolation loss and surface storage components are zero. Details of the different model components are described below.

Estimation of Model Parameters. Various methods are available to estimate the reference crop evapotranspiration (ET_0) [8,1]. However, based on the availability of meteorological data of the study area, the Hargreaves method [15] of estimating ET_0 was selected, which is as given below:

$$ET_0 = 0.0023 \times (T_{mean} + 17.8) \times (T_{max} - T_{min})^{0.5} \times R_a \quad (2)$$

where:
ET_0 [mm·day^{-1}] - reference evapotranspiration,
R_a [mm·day^{-1}] - extraterrestrial radiation,
T_{max} [°C] - maximum air temperature for a given day,
T_{min} [°C] - minimum air temperature for a given day,
T_{mean} [°C] - mean air temperature for a given day.

Crop Evapotranspiration. The crop evapotranspiration (*ETc*) was calculated using the following equation.

$$ETc = ET_0 \times K_c \quad (3)$$

where:
ETc [mm·day^{-1}] - crop evapotranspiration,
K_c [-] - crop coefficient.

K_c values of different field crops at the different growing stages were taken from [1], [7] and [8].

Root Zone Depth. Root depth was modelled using the algorithm developed by [3]. This model describes root depth by a sigmoid development of the roots from planting date until maturity. The empirical model is given by:

$$Z_t = Z_{max} \times [0.5 + 0.5 \times \sin\{3.03 \times (t/t_m) - 1.47\}] \quad (4)$$

where:
Z_t [cm] - root depth on t^{th} day after sowing,
Z_{max} [cm] - maximum possible root depth,
t [days] - day after planting,
t_m [days] - time for the full development of the root zone.

Maximum root depth of different field crops has been reported by [8].

Soil Water Depletion Factor. The soil water depletion factor (p_t) was computed by the numerical approximation of adjusting p for maximum *Etc* [1], which is as given below.

$$p_t = p_{table} + 0.04 \times (5 - ETc) \tag{5}$$

where:

p_{table} [-] - table value of soil water depletion factor of crops.

Effective Rainfall. Several methods of estimating effective rainfall for irrigation scheduling are widely used. Those are based on long experiences and have been found to work quite satisfactorily in specific conditions under which they were developed [1]. For the study area, the effective rainfall for crops other than rice was considered as 70% of the average seasonal rainfall. For rice crop, 50 to 80% of total rainfall was assumed effective [1].

Actual Evapotranspiration. The actual evapotranspiration was estimated by using the linear model as developed by [7].

$$ETa_t = ETc_t, if\ (SMC_t - SMC_w) \times Z_t \geq (1 - p_t)(SMC_{fc} - SMC_w) \times Z_t \tag{6}$$

Otherwise,

$$ETa_t = \frac{(SMC_t - SMC_w) \times Z_t \times ETc_t}{(1 - p_t)(SMC_{fc} - SMC_w) \times Z_t} \tag{7}$$

where:

ETa_t [cm·day^{-1}] - actual evapotranspiration,
SMC_{fc} [cm·m^{-1}] - soil moisture content at field capacity,
SMC_w [cm·m^{-1}] - soil moisture content at wilting point.

The SMC_{fc} component in Eqs. 6 and 7 has to be replaced by SMC_{sat} (saturated *SMC*) and the component ETc_t in both the equations has to be replaced by ETm_t (maximum evapotranspiration) for rice crop.

Soil Moisture Depth. Soil moisture depth was calculated as below.

$$Da_t = \left[\left(SMC_{fc} - SMC_t\right) \times Z_t + SS_t\right]\emptyset \tag{8}$$

where:

ϕ [-] - deficit ratio (fraction).

For rice crop, the term SMC_{fc} in Eq. 8 should be replaced by SMC_{sat} and for non-rice crops, surface storage (*SS*) equals zero.

Depth of Irrigation and Water Delivery Depth. Further, the depth of irrigation (*ID*) and the water delivery depth (*WD*) were calculated by using the equations as given below.

$$ID_t = D_a / E_a \tag{9}$$

$$WD_t = E_c \times E_d \times ID_t \tag{10}$$

where:

E_a [-] - application efficiency (fraction),
E_c [-] - conveyance efficiency (fraction),
E_d [-] - distribution efficiency (fraction).

The conveyance, distribution, and application efficiency were assumed to be 70, 70 and 80%, respectively [8].

Actual Crop Yield. The actual crop yield (Y_a) was calculated by using the additive approach of the dated water-production function [7].

$$\frac{Y_a}{Y_m} = \sum_{r=1}^{r} \left[1 - Ky_r \left(1 - \frac{ETa_r}{ETc_r}\right)\right] \tag{11}$$

where:

Y_m [kg·ha^{-1}] - potential crop yield,

r [-] - no. of yield stages,

Ky_r [-] - yield response factor.

Ky values of different field crops were taken from [8]. While the *Ky* values for rice were considered as 1.1 in initial stage, 1.1 in crop development stage, 2.4 in flowering stage, 2.4 in grain formation stage, and 0.33 in ripening stage [23].

RESULTS AND DISCUSSION

In the present study, five major *rabi* crops, such as rice, wheat, maize, greengram and mustard, are considered for the development of their corresponding *IMS*s. Water use efficiency was used as an indicator to compare the performances of different *IMS*s under consideration.

Deficit Irrigation Strategy. Under the *DI* strategy, the deficit ratios were considered to range from 0.1 to 1.0 with an increment of 0.1. Deficit ratio of 1.0 indicates that the irrigation is applied to bring the moisture in the root zone to field capacity, whereas deficit ratio of 0.1 indicates 90% reduction in irrigation or the degree of deficit as 90%. The developed ISM was run for the irrigation intervals of 7, 14, 21 and 28 days for non-rice crops and 4, 8 and 12 days for rice crop. The *WUE* of wheat was found to increase with increase in deficit ratio up to 0.7 for both 7 and 14 days irrigation intervals (Fig. 3a). Beyond this level the *WUE* was reduced for both the irrigation intervals. There was always increasing trend in *WUE* for 21 and 28 days irrigation intervals. Maximum *WUE* was attained at the deficit ratio of 0.7 (30% deficit) and irrigation interval of 14 days. Hence, 30% *DI* to wheat at an interval of 14 days can be the best *IMS* under *DI* strategy.

For maize, the *WUE* was found to increase with increase in deficit ratio up to 0.7 and 7 days irrigation interval, which then reduced with further increase in deficit ratios (Fig. 3b). At 14 days irrigation interval the *WUE* was found to increase up to deficit ratio of 0.8 and then reduced. But the *WUE* of maize at both 21 and 28 days irrigation intervals went on increasing up to the deficit ratio of 0.9. Comparison of *WUE*s for all the irrigation intervals and deficit ratios showed that 30% DI to maize at an interval of 7 days may be the best *IMS* under *DI* strategy. The trend of *WUE* in case of rice was increasing up to the deficit ratio of 0.8 and 4 days irrigation interval, which was then altered, whereas the trend of *WUE* was found increasing up to the deficit ratio of 0.9 at both 8 and 12 days irrigation intervals (Fig. 3c). Among all the deficit ratios and irrigation intervals considered, the *WUE* was highest for 20% *DI* at 4 days interval that could be taken as the best *IMS* for rice under *DI* strategy.

The *WUE* of greengram was found to increase with increase in deficit ratio up to 0.7 and at 7 days irrigation interval, which then decreased with increase in deficit ratios (Fig. 3d). At 14 days irrigation interval the *WUE* of greengram was found to increase up to deficit ratio of 0.8 and then reduced. But at both 21 and 28 days irrigation intervals, the *WUE* followed the increasing trend up to the deficit ratio of 0.9 and then decreased. Comparison of *WUE*s at various deficit ratios and irrigation intervals revealed highest *WUE* for 20% *DI* at 14 days interval. Hence, it may be considered as the best *IMS* for greengram under *DI* strategy. The *WUE* of mustard was found to increase with increase in deficit ratio up to 0.8 at 7 days irrigation interval, and then decreased with further increase in deficit ratios (Fig. 3e). At 14 days and 28 days irrigation intervals, the *WUE* of maize was found to increase up to the deficit ratio of 0.9 and then decreased. The *WUE* of mustard showed a decreasing trend at 21 days irrigation interval, after achieving the highest value at the deficit ratio of 0.7. Among all the irrigation intervals and deficit ratios considered, the *WUE* of mustard was found to be highest for 20% *DI* at 7 days interval, which may be considered as the best *IMS* under *DI* strategy.

Fixed Depth Irrigation Strategy. In this strategy, three different fixed depths (6, 8 and 10 cm for non-rice crops and 9, 12 and 15 cm for rice crop) were considered. The effects of those fixed depths and irrigation intervals on the yield and *WUE* of crops was studied. The *WUE* of wheat was found to decrease with increase in depth of irrigation per application for all the irrigation intervals except 28 days (Fig. 4a), where the *WUE* showed a reverse trend up to 80 mm irrigation per application. The *WUE* was found to be the highest for 60 mm irrigation per application at 21 days irrigation interval. Thus, it can be taken as the best *IMS* in case of fixed depth irrigation strategy. Similar to wheat, the *WUE* for maize was also found to decrease with increase in depth of irrigation per application at all irrigation intervals (Fig. 4b). Comparing *WUE* of maize at all irrigation intervals, the *WUE* was found to be the highest at 28 days irrigation interval with 60 mm irrigation per application that may be considered as the best *IMS* for maize in case of fixed depth irrigation strategy.

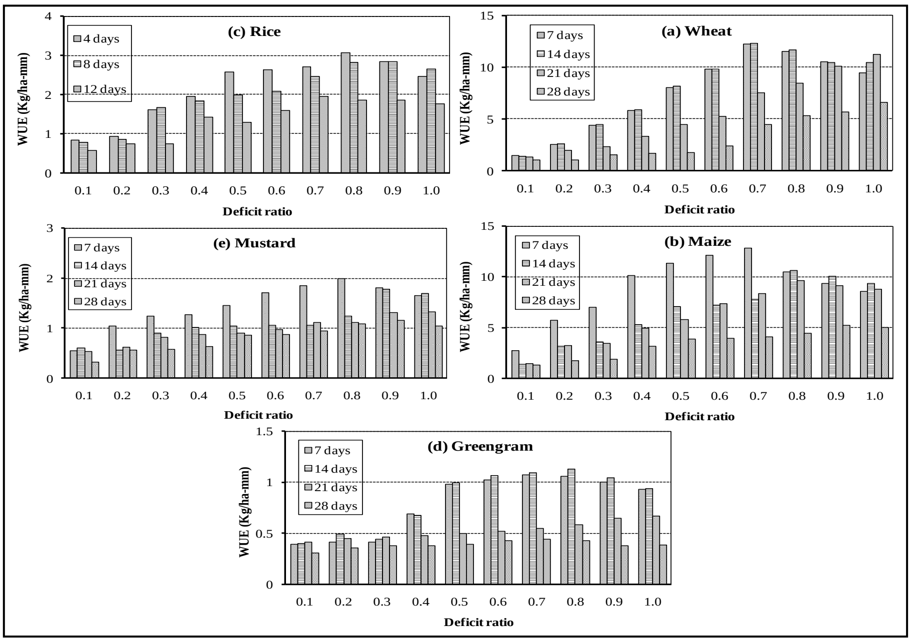

Figure 3. WUE of different rabi crops under DI strategy at various irrigation intervals

The WUE of rice showed a decreasing trend with increase in depth of irrigation per application at all irrigation intervals considered (Fig. 4c). The *WUE* was found to be the highest for irrigation depth of 90 mm at an interval of 8 days. Hence, 90 mm irrigation per application to rice at an interval of 8 days can be followed as the best *IMS* for rice under the fixed depth irrigation strategy. The *WUE* for greengram decreased with increase in depth of irrigation per application at all irrigation intervals except 28 days (Fig. 4d), where the *WUE* first increased and then decreased. Comparing *WUE* of greengram at all irrigation intervals, it was found that the *WUE* was highest for 60 mm irrigation per application at 21 days interval. Thus, 60 mm irrigation per application at 21 days interval can be the best *IMS* for greengram in case of fixed depth irrigation strategy. At all irrigation intervals, the *WUE* of mustard was found to decrease with increase in depth of irrigation per application (Fig. 4e). However, the *WUE* was highest under 60 mm irrigation per application at 28 days interval, which may be taken as the best *IMS* for mustard in case of fixed depth irrigation strategy.

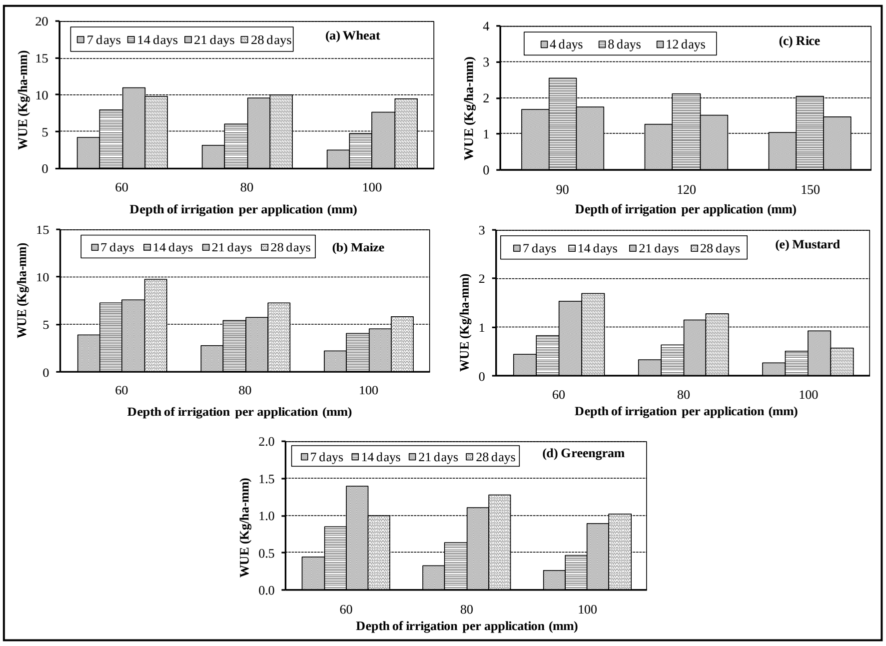

Figure 4. WUE of different rabi crops under fixed depth IMS at various irrigation intervals

CONCLUSIONS

In the above section, best *IMS*s of various crops separately under fixed depth application and deficit irrigation at different intervals are presented. However, it is essential to compare the crop-wise *IMS*s for both *DI* and fixed depth application strategy so as to evolve the best IMSs of crops giving highest *WUE*. Optimum *IMS* of each crop was found out by comparing the best *IMS*s under full irrigation, deficit irrigation and fixed depth application. It was found that 30% *DI* to wheat at an interval of 14 days is the most efficient *IMS* and the best IMS for maize is to irrigate with 30% *DI* at an interval of 7 days. Irrigating rice with 20% *DI* at an interval of 4 days is the efficient *IMS* and the most effective *IMS* for greengram is to apply 60 mm of water per irrigation at an interval of 21 days. Mustard gives maximum *WUE* when it is irrigated with 20% *DI* at an interval of 7 days.

Since agricultural area is diminishing day by day due to ever increasing population and rapid industrialization, hence, it is inevitable to grow more to earn more from the limited land and water resources. It can be seen from the above results that deficit irrigation practice can be a viable option to achieve better *WUE* under water limiting environments. Hence, the crop-wise irrigation management strategies as presented above may be adopted by the beneficiaries of the selected canal command area during rabi season so as to bring more area under crops, which in turn will enhance the production potential of the command area.

BIBLIOGRAPHY

[1] Allen, R.G., Pereira, L.S., Raes, D., Smith, M. 1998. C*rop evapotranspiration: Guidelines for predicting crop water requirements*. Irrigation and Drainage paper, No. 56, FAO, United Nations, Rome, Italy.

[2] Aydinsakir, K., Erdal, S., Buyuktas, D., Bastug, R., Toker, R. 2013. The influence of regular deficit irrigation applications on water use, yield and quality components of two corn (Zea Mays L.) genotypes. *Agricultural Water Management*, 128: 65–71.

[3] Borg, H., Grimes, D.W. 1986. Depth development of roots with time: An empirical description. *Transactions of the ASAE*, 29(1): 194–197.

[4] CGWB. 1998. *Studies on conjunctive use of surface and groundwater resources in Hirakud irrigation project, Orissa*. Central Ground Water Board, Ministry of Water Resources, Govt. of India.

[5] Domínguez, A., Jiménez, M., Tarjuelo, J.M., de Juan, J.A., Martínez-Romero, A., Leite, K.N. 2012. Simulation of onion crop behavior under optimized regulated deficit irrigation using MOPECO model in a semi-arid environment. *Agricultural Water Management*, 113: 64–75.

[6] Domínguez, A., Tarjuelo, J.M., de Juan, J.A., López-Mata, E., Breidy, J., Karam, F. 2011. Deficit irrigation under water stress and salinity conditions: the MOPECO-salt model. *Agricultural Water Management*, 98(9): 1451–1461.

[7] Doorenbos, J., Kassam, A. H. 1979. *Yield response to water*. Irrigation and Drainage paper, No. 33, FAO, United Nations, Rome, Italy.

[8] Doorenbos, J., Pruitt, W. O. 1977. *Crop water requirements*. Irrigation and Drainage paper, No. 24, FAO, United Nations, Rome, Italy.

[9] Du, T., Kang, S., Sun, J., Zhang, X., Zhang, J. 2010. An improved water use efficiency of cereals under temporal and spatial deficit irrigation in north China. *Agricultural Water Management*, 97(1): 66–74.

[10] English, M., Nuss, G. S. 1982. Designing for deficit irrigation. *Journal of Irrigation and Drainage Division*, 108(2): 91–106.

[11] Ertek, A., Kara, B. 2013. Yield and quality of sweet corn under deficit irrigation. *Agricultural Water Management*, 129: 138–144.

[12] Fang, Q., Ma, L., Yu, Q., Ahuja, L.R., Malone, R.W., Hoogenboom, G. 2010. Irrigation strategies to improve the water use efficiency of wheat–maize double cropping systems in north China plain. *Agricultural Water Management*, 97(8): 1165–1174.

[13] Gorantiwar, S.D., Smout, I.K. 2006. Productivity and equity of different irrigation schedules under limited water supply. *Journal of Irrigation and Drainage Engineering, ASCE*, 132(4): 349–358.

[14] Hargreaves, G.H., Samani, Z.A. 1984. Economic considerations of deficit irrigation. *Journal of Irrigation and Drainage Engineering, ASCE*, 110(4): 343–358.

[15] Hargreaves, G.H., Samani, Z.A. 1985. Reference crop evapotranspiration from temperature. *Applied Engineering in Agriculture*, 1: 96–99.

[16] IPCC. 2007. Climate change: Impacts, adaptation and vulnerability. Fourth Assessment Report of IPCC Working Group II. Cambridge, UK.

[17] Karimi, P., Qureshi, A.S., Bahramloo, R., Molden, D. 2012. Reducing carbon emissions through improved irrigation and groundwater management: A case study from Iran. *Agricultural Water Management*, 108: 52–60.

[18] Mushtaq, S., Moghaddasi, M. 2011. Evaluating the potentials of deficit irrigation as an adaptive response to climate change and environmental demand. *Environmental Science Policy*, 14(8): 1139–1150.

[19] Patanè, B., Tringali, S., Sortino, O. 2011. Effects of deficit irrigation on biomass, yield, water productivity and fruit quality of processing tomato under semi-arid mediterranean climate conditions. *Scientia Horticulture*, 129(4): 590–596.

[20] Quanqi, L., Xunbo, Z., Yuhai, C., Songlie, Y. 2012. Water consumption characteristics of winter wheat grown using different planting patterns and deficit irrigation regime. *Agricultural Water Management*, 105: 8–12.

[21] Sarkar, S., Basu, B., Kundu, C.K., Patra, P.K. 2012. Deficit irrigation: an option to mitigate arsenic load of rice grain in West Bengal, India. *Agriculture, Ecosystem and Environment*, 146(1): 147–152.

[22] Shangguan, Z., Shao, M., Horton, R., Lei, T., Qin, L., Ma, J. 2002. A model for regional optimal allocation of irrigation water resources under deficit irrigation and its applications. *Agricultural Water Management*, 52(2): 139–154.

[23] Srinivasa, A.P., Umamahesh, N.V., Viswanath, G.K. 2006. Optimal irrigation planning under water scarcity. *Journal of Irrigation and Drainage Engineering, ASCE*, 132(3): 228–237.

[24] Tejero, I.G., Zuazo, V.H.D., Bocanegra, J.A.J., Fernández, J.L.M. 2011. Improved water-use efficiency by deficit-irrigation programmes: implications for saving water in citrus orchards. *Scientia Horticulture*, 128(3): 274–282.

[25] Trimmer, W.L. 1990. Applying Partial Irrigation in Pakistan. *Journal of Irrigation and Drainage Engineering, ASCE*, 116(3): 342–353.

[26] Tyagi, N.K., Singh, O.P., Dhruvanarayana, V.V. 1979. Evaluation of water management systems in a tubewell irrigated farm. *Agricultural Water Management*, 2(1): 67–78.

[27] Wolff, P., Stein, T.-M., 1999. Efficient and economic use of water in agriculture-possibilities and limits. *Natural Resources Development*, 49/50: 151–159.

[28] Zou, X., Li, Y., Gao, Q., Wan, Y. 2012. How water saving irrigation contributes to climate change resilience – a case study of practices in China. *Mitigation and Adaptation Strategies for Global Change*, 17(2): 111–132.

UPRAVLJANJE NAVODNJAVANJEM NE-MONSUNSKIH USEVA U OBLASTI GLAVNOG KANALA U ISTOČNOJ INDIJI, U USLOVIMA OGRANIČENOG SNABDEVANJA VODOM

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Sažetak: Izražen nedostatak vode u ne-monsunskom periodu (*rabi*) u oblasti Hirakud kanala i istočnoj Indiji zahteva efikasne strategije upravljanja navodnjavanjem (*IMS*s). Ovo istraživanje je sprovedeno radi analize uticaja različitih *IMS* – punog i defcictarnog navodnjavanja i različitih *rabi* useva na efikasnost upotrebe vode i razvoja najefikasnije *IMS*. Različiti parametri bilansa vode su ocenjivani na dnevnoj bazi i izračunati su stvarni prinosi za pet glavnih *rabi* useva. Najbolje *IMS* za pšenicu, kukuruz, pirinač, zlatni pasulj i slačica imale su 30% deficita navodnjavanja u periodima od 14 dana, 30% deficita navodnjavanja u periodima od 7 dana, 20% deficita navodnjavanja u periodima od 4 dana, 60 mm vode po aplikaciji i u periodima od 21 dan i 20% deficita navodnjavanja u periodima od 7 dana, redom. Imajući u vidu siromašne izvore vode i stalno rastuću populaciju, veoma je neophodno primeniti ove strategije sa ciljem dobijanja veće obradive površine i unapređenja proizvodnog potencijala ove oblasti.

Ključne reči: *deficit navodnjavanja, primena na stalnu dubinu, balans zemljišne vlage, efikasnost upotrebe vode*

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FOURIER TRANSFORM – NEAR INFRARED SPECTROSCOPY FOR RAPID AND NONDESTRUCTIVE MEASUREMENT OF AMYLOSE CONTENT OF PADDY

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Abstract: The quality and quantity of amylose are two important factors that determine the quality of paddy. The feasibility of developing a technique for rapid monitoring of paddy quality by using Fourier Transform - Near Infrared (*FT-NIR*) Spectroscopy combined with chemometrics was investigated. Spectra of 250 paddy samples were collected by using an integrating sphere accessory. The amylose content was analyzed by reference method. It ranged from 13.24 to 27.93%. The spectral data was analyzed by partial least squares (PLS) algorithm and calibration model generated. Correlation coefficient (R^2) for the calibration model was >0.78 with root mean square error of estimation (*RMSEE*) < 1.8. The validation model had R^2> 0.72 and root mean square error of cross-validation (*RMSECV*) < 2. *FT-NIR* spectroscopy identified samples containing amylose at 5184 and 6834 cm^{-1} wave number. A fast, simple and accurate method to quantify the amylose of paddy was developed by using FT-NIR spectroscopy.

Key words*: paddy, amylose, chemometrics, FT-NIR spectroscopy, calibration*

INTRODUCTION

Paddy is one of the staple food crops in India. *ADT* 43 is the most popular paddy variety grown in all the parts of Tamil Nadu, the reason behind that of *ADT* 43 are resistant to stem borer and gall midge, high tillering and fine rice [1,2]. About 70% of the paddy produced in India is stored at farm level. A small proportion of paddy is used as an ingredient in processed foods and as feed but the bulk is consumed as cooked rice.

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This pattern of usage results in the need to store rice over varying periods [3]. Quality maintenance is the main aim of such storage techniques. The economics of the grain which dictate the market value of the grain must be as high as possible during storage and on delivery to the customer [4]. Any attempt to generalize on the quality attributes of rice is accomplished by the diversity in tastes, but the predominant attributes are associated with its starch composition and amylose content.

Amylose is the important component in paddy which affects the parboiling, cooking and eating quality. Changes in the amylose content during storage affects the textural and rheological properties of cooked rice. Amylose content is directly related to water absorption, volume expansion and fluffiness of cooked grains. Thermal and pasting behavior of the aged paddy also depends on the degree of gelatinization. Disruption of the crystalline structure of starch granules during cooking decreases. The structural modifications of starch and protein gels may enhance the hardness of the cooked rice prepared from the aged samples [5].

Ozone fumigation is a novel method used to control the insects in stored grains [6-8]. It highly influences the amylose content changes as compared to other chemical composition. The concentration of ozone optimized based on the amylose changes. Hence, to check the amylose content of paddy grains before and after ozone treatment the study is essential. This study is also useful for *CWC* (central warehousing corporation) at the time of procurement of paddy from farmers and various paddy research institutions for analyzing the quality of paddy [9].

For the determination of amylose content by laboratory method, usually powdered and dry material is needed. The problems in the laboratory method of analysis are length of time required, destructive nature (without removal of husk, it is not possible to quantify the amylose content of rice in laboratory methods) and the requirement of hazardous chemicals as well as their disposal.

NIR spectroscopy is a fast technique that possesses the potential selectivity for screening the products based on qualitative attributes, when coupled with chemometric data analysis techniques [10]. Infrared spectroscopy is a technique that has been proposed as an excellent alternative to traditional methods due to its multiple characteristics such as simplicity, rapidity, reliable, cost effectiveness, potential for routine analysis and non requirement of skilled operator [11]. Monitoring the quality of paddy is a difficult task for farmers, rice researchers and food scientists. The aim of this research was to assess the performance of *NIR* spectroscopy combined with chemometrics in determining the amylose content of paddy.

MATERIAL AND METHODS

Paddy samples. Paddy (*ADT* 43) was obtained from central farm, located in Tamil Nadu Agricultural University and Central Warehousing Corporation, Trichy, India and used for the study. The paddy was cleaned manually to remove all foreign materials such as dust, dirt, chaff and immature paddy.

FT-NIR spectroscopy. *FT-NIR* spectra were recorded on multipurpose analyzer (Bruker Optics, Germany) equipped with an integrated Michelson interferometer; highly sensitive PbS 12000–4000 cm^{-1} detector, multiple *NIR* measurement accessories for different sampling techniques combined with *OPUS* 7.2 software. For the current study spectra's were collected in diffuse reflectance mode with sphere macro sample integrating sphere measurement channel. The spectra were acquired in reflectance mode directly on the paddy, over the range 12000–4000 cm^{-1}. Spectra of 250 paddy samples were collected for calibration by using an integrating sphere accessory. For each sampling, 5 g of paddy were analyzed at room temperature and the average spectra were used for further evaluations [9].

Destructive method of estimation of amylose content in paddy. The amylose contents (% w/w) from grains were determined by the spectrophotometric standard method [12]. A total of 100 mg of granules was homogenized with 1 ml of 95% ethanol and 9 ml of 1 M NaOH. The sample was heated for 10 min. in a boiling-water bath to gelatinize the starch. After cooling, it was transferred into a volumetric flask and the volume was made up to 100 ml with water. Then 1 ml of 1 M acetic acid and 2 ml of iodine solution (0.2% I_2, 2% *KI*) were added to a 5-ml aliquot. The solution was made up to 100 ml with water and allowed to stand for 10 min. Spectrophotometric quantification was performed at 620 nm, with a spectrophotometer, using the multipoint working curve method with two repetitions and quartz cells of 10 mm path length. Two determinations were made on separate test portions taken from the same sample in each of the replicates. The apparent amylose content was calculated using an equation obtained from the standard curve.

Preprocessing methods. In this study, three data preprocessing methods were applied comparatively; these were vector normalization, first derivative and first derivative plus vector normalization. Each spectrum is corrected individually by first centering the spectral value. Then, the centered spectrum is scaled by the standard deviation calculated from the individual spectral values. Vector normalization normalizes a spectrum by first calculating the average intensity value and subsequent subtraction of this value from the spectrum. First derivative eliminate baseline drifts and small spectral differences are enhanced [9].

Data analysis. The *OPUS* software 7.2 was used for processing the data and *FT-NIR* models were developed with the full calibration data set. The spectral data were analyzed using PLS regression with various preprocessing techniques.

The performance of final *PLS* model was evaluated in terms of coefficient of determination (R^2) and root mean square error of cross validation (*RMSECV*). The accuracy of the calibration models is obtained according to the highest values of R^2 and lowest *RMSECV* and *RMSEP* values.

$$SSE = \sum [\mathrm{Re}\,sidual]^2 \tag{1}$$

where:

Residual [-] - experimental value / predicted value.

The coefficient of determination (R^2) gives the proportion of variability of the property that is described by the model.

$$R^2 = \left(1 - \frac{SSE}{\sum (y_i - y_m)^2}\right) \times 100 \tag{2}$$

where:

$y_i = i^{ih}$ [-] - observation of experimental value,

y_m [-] - mean of the reference results for all samples.

Where, n is the number of samples in the validation set and y_i and $\bar{y}_i$ is the measured and predicted value of the i^{th} observation in the test set, respectively. The number of *PLS* factors included in the model is chosen according to the lowest *RMSECV*.

RESULTS AND DISCUSSION

Spectra investigation. The spectra of original data recorded in the near-infrared region (4000–12500 cm^{-1}) are shown in Fig. 1. From the figure it is seen that almost all the sample is linear within the range of study and thus may give superior results [13]. As the spectra show similar basic *FT-NIR* spectral patterns, mathematical transformations were required to use the *FT-NIR* data for quantitative analysis.

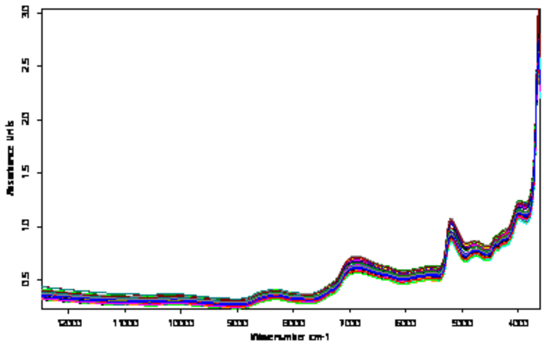

Figure 1. Spectra of paddy samples

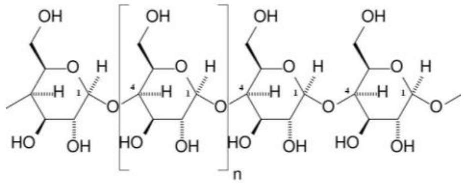

Figure 2. Molecular structure of amylose

Fig. 1. also shows the *FT-NIR* spectra of amylose content which has major peaks at absorbance bands (wave numbers) of 3633.42, 3996, 5184, 6834.85 and 8316 cm^{-1}. As seen from Fig. 1, there are water absorption bands around 3633.42 and 3996 cm^{-1} wave number are generally due to O–H stretching of water molecule. These were excluded during analysis. The structure of amylose is shown in Fig. 2. A group of atoms in a molecule may have multiple modes of oscillation caused by stretching and bending motions of the amylose group. The strongest absorption of the spectra was at 5184 cm^{-1} related to the combination of O-H stretching and O-H bending of amylose molecule. Major peaks at absorbance bands or wave numbers of 6834.85 cm^{-1} may be due to the combination of first overtone of O-H anti-symmetric stretching and O-H symmetric stretching of amylose. The weak absorption bands at 8316 cm^{-1} may be due to second overtone of symmetric stretching (–CH bonds) of methyl (–CH_3) groups. The OH and –

CH bond vibrations are caused by ingredients such as amylose, protein and water compounds. The frequency that characterizes the stretching vibration of a given bond is proportional to the bond dissociation energy.

Chemometric analysis. The *NIR* spectra were transformed to its first-derivative using PLS function. The transformed spectra were cross-validated to generate calibration models. Cross validation was also done to check the calibrated values are shown in Fig. 3 and 4. It has been reported that the number of samples to develop the calibration model should cover the desired quantitation range for the specific analyses, with a minimum of 20–50 samples depending on the complexity of the problem [14]. Generally large calibration data sets are preferable, because they will provide more accuracy about the variability expected in validation samples. However large number of samples implies that it will take more time and chemical to create the model. Typically open calibration curves are developed, meaning that there is always the possibility to add more data points into the calibration curve to make it more robust [10].

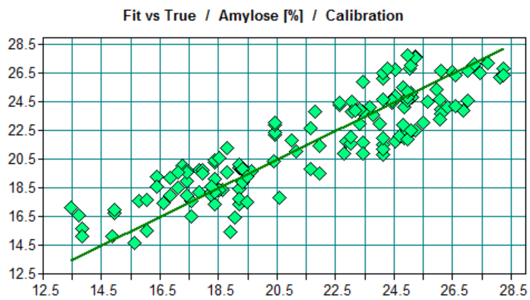

Figure 3. Calibration model of amylose

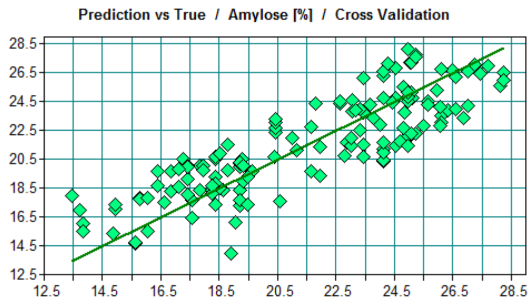

Fig.4. Validation model of amylose

Models were evaluated in terms of correlation coefficient (R^2), root mean square error of estimation (*RMSEE*) and root mean square error of cross validation (*RMSECV*). Figs. 5, 6 and 7 shows the R^2, *RMSECV* and *RMSEE* values plotted as a function of *PLS* factors for determining amylose content of paddy with first derivative and vector normalization method as the pre-processing technique. Seen from Fig. 5, R^2 value increased and reached an optimum value at *PLS* factor 10. *RMSECV* value decreases sharply up to the *PLS* recording rank of 8 and increased slightly as *PLS* factor increases from 8 to 10 (Fig. 6). Fig. 7 shows the *RMSEE* value decreases sharply, if *PLS* factor increased from 1 to 10 and reached a minimum value at PLS factor 10. If PLS factor increases it increase the R^2 value and decrease the *RMSECV* and *RMSEE* values. The optimum number of factors is determined by the lowest *RMSECV* and *RMSEE* values and highest values for R^2. From the Figs. 5, 6 and 7, conform that initial *PLS* factor had high impact on R^2, *RMSECV* and *RMSEE* values.

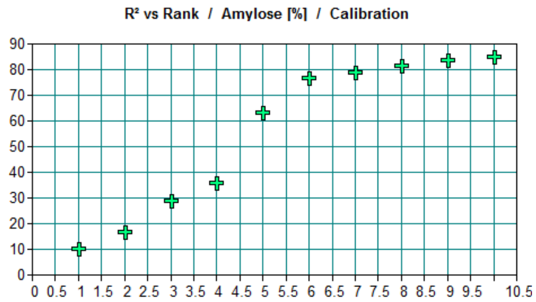

Figure 5. R^2 value as a function of PLS factor

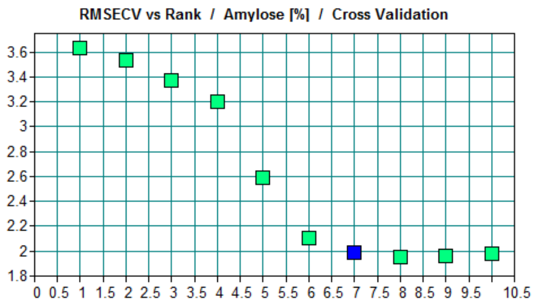

Figure 6. RMSECV value as a function of PLS factor

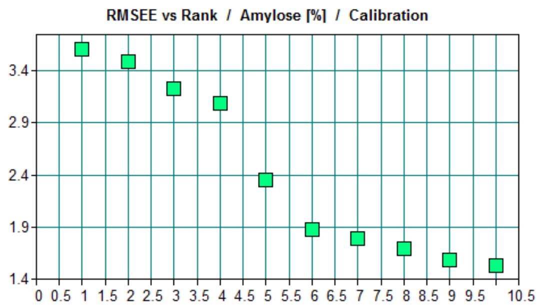

Figure 7. RMSEE value as a function of PLS factor

PLS regression method gave R^2 and *RMSECV* values of 78.6 and 1.99, respectively. Correlation coefficient (R^2) indicates the strength and direction of the linear relationship between predicted values and reference values [15]. Ratio of standard deviation to standard error of prediction gives *RPD* (residual predictive deviation) value. *RPD* value was more than 1.8. If *RPD* value lower than 1.5 is considered insufficient for most applications while *NIR* cross validation models with values greater than two is considered excellent [16]. The results of this study clearly indicate the efficiency of *FT-NIR* for this application.

CONCLUSIONS

An ozone treated paddy grains (*ADT* 43) amylose content was tested using *FT-NIRS. NIR* spectroscopy technique has potential to quantify the amylose from paddy. A fast, simple and accurate method for determination of amylose was demonstrated by using *NIR* spectroscopy at a low cost. It allowed for faster sample preparation and ease of use as compared to laboratory method. The total time required for sample preparation and analysis was less than 2 minutes, compared to 16 h required for amylose content determination by reference method. The overall results demonstrate that *FT-NIR* spectroscopy with *PLS* factor calibration could be successfully applied as a rapid method for quantification of amylose of paddy. It might be an application for paddy quality monitoring in the Central Warehousing Corporation, Food Corporation of India and various rice research stations by using *FT-NIR* spectroscopy.

BIBLIOGRAPHY

[1] Ravi, P., Venkatachalam, T. 2014. Important engineering properties of paddy. *Poljoprivredna tehnika, 39*(4), 73-83.

[2] Pandiselvam, R., Thirupathi, V., Mohan, S. 2015. Engineering properties of rice. *Poljoprivredna tehnika*, 2015/3, p.p. 69–78.

[3] Zhou, K., Robards, S., Helliwell, Blanchard, C. 2001. Ageing of Stored Rice: Changes in Chemical and Physical Attributes. *J. Cereal Sci.*, 33, 1-15.

[4] Wrigley, C.W., Gras, P.W., Bason, M.L. 1994. Maintenance of grain quality during storage – prediction of the conditions and period of safe storage. *Proceedings of the 6 th international working conference on stored product protection*, 2, 666-670.

[5] Tananuwong, K., Malila, Y. 2011. Changes in physicochemical properties of organic hulled rice during storage under different conditions. *Food Che.*, 125, 179–185.

[6] Pandiselvam, R., Thirupathi, V. 2015. Reaction kinetics of Ozone gas in Green gram (Vigna radiate). *Ozone: Science & Engineering,* 37, 1-7.

[7] Ravi, P., Venkatachalam, T., Rajamani, M. 2015. Decay Rate kinetics of Ozone Gas in Rice Grains. *Ozone: Science & Engineering,* Vol. 37, Issue 5, 2015.

[8] Pandiselvam, R., Thirupathi, V., Anandakumar, S. 2015. Reaction Kinetics of Ozone Gas in Paddy Grains. *Journal of Food Process Engineering*. Vol. 38/6, p.p. 594–600.

[9] Ravi, P., Venkatachalam, T., Palanisamy, V. 2014. Fourier transform near-infrared spectroscopy for nondestructive and rapid measurement of moisture content of paddy. *Poljoprivredna tehnika*, *39*(3), 31-40.

[10] Shiroma, C., Rodriguez-Saona, L. 2009. Application of NIR and MIR spectroscopy in quality control of potato chips. *J. Food Composition and Analysis,* 22, 596–605.

[11] Karoui, R., Mounem, A., Dufour, E., Pillonel, L., Shcaller, E., Picque, D. 2006. A comparison and joint use of NIR and MIR spectroscopic methods for the determination of

some parameters in European Emmental cheese. *European Food Research and Tech.,* 223, 44–50.

[12] ISO. 1987. *International Organization for Standardization (ISO)* 6647. International Organization for Standardization, Geneva

[13] Jha, S.N. 2007. Nondestructive Determination Sweetness of Orange Juice using Portable Near Infrared Spectroscopy. *J. Agr. Eng.*, 44(3), 10-14.

[14] Chen, C., Cai, W., Shao, X. 2007. An Adaptive for selecting representative calibration samples in the continuous wavelet domain for near-infrared spectral analysis. *Analytical and Bio analytical Che.*, 387, 1041–1048.

[15] Segtnan, V.H., Isaksson, T. 2000. Evaluating near infrared techniques for quantitative analysis of carbohydrates in fruit juice model systems. *J. Near Infrared Spect.,* 8, 109–116.

[16] Chang, C.W., Laird, D.A., Mausbach, M..J., Hurburgh, C.R. 2001. Near infrared reflectance spectroscopy-principal component analysis of soil properties. *Soil Sci. Soc. Am.*, 65, 480–490.

FURIJEOVA TRANSFORMACIJA - SPEKTROSKOPIJA U BLISKOJ INFRACRVENOJ OBLASTI ZA BRZO I NEDESTRUKTIVNO MERENJE SADRŽAJA AMILOZE U ZRNU PIRINČA

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Sažetak: Kvalitet i kvantitet amiloze su dva značajna faktora koja određuju kvalitet pirinča. Ovede je razvijena tehnika brzog merenja kvaliteta pirinča upotrebom Furijeove transformacije – spektroskopije u bliskoj IR oblasti kombinovane sa hemometrijom. Analiziran je spektar 250 uzoraka pirinča integrisanim svernim uređajem. Sadržaj amiloze iznosio je 13.24 do 27.93%. Spektralni podaci su analizirani algoritmom parcijalnih najmanjijh kvadrata i generisan je kalibracioni model. Koeficijent korelacije bio je >0.78 sa srednjim kvadratom odstupanja < 1.8. Validacioni model imao je R^2> 0.72 i srednji kvadrat odstupanja unakrsne procene < 2. *FT-NIR* spektroskopijom su identifikovani uzorci koji sadrže amilozu sa talasnim brojevima 5184 i 6834 cm^{-1}. Tako je razvijen brz, jednostavan i pouzdan metod određivanja sadržaja amiloze.

Ključne reči*: pirinač, amiloza, hemometrija, FT-NIR spektroskopija, kalibracija*

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