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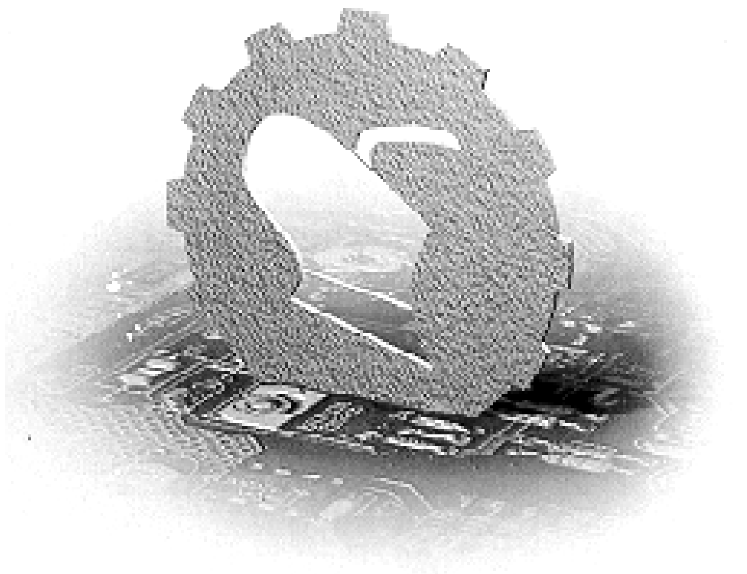

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COMPUTER PROGRAM FOR COST ESTIMATION OF AGRICULTURAL MACHINES

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North Eastern Regional Institute of Science and Technology, Nirjuli (Itanagar), India

Abstract: A user-friendly computer program is developed in Visual Basic environment to determine the all types of machinery costs on hour and hectare basis. The program is also capable to compute breakeven area and time of use of machines to get back return on investment. The input parameters of the developed program are mainly initial price, life of machine, rate of interest, fuel cost, labor wages etc. for power source as well as implement. The total cost is being calculated in two heads namely fixed and variable cost. The fixed cost consists of depreciation, interest, taxes, housing and insurance cost, while variable costs includes fuel, lubrication, wages, repair and maintenance cost. The developed program successfully calculates the cost of operation in rupees per hour and in rupees per hectare of different combinations of power sources and implements. The breakeven analysis of any combination of the power source and implement can also be analyzed. This program can be a useful tool for suggesting the farmers in purchasing a machine as well as in deciding the custom hiring rates etc. This can also help to entrepreneurs who are engaged in custom hiring services to decide the hiring rate of different machinery on the basis of breakeven analysis.

Key words*: cost of operation, breakeven point, computer program*

INTRODUCTION

Agriculture is the most important sector of Indian economy. As per recent trends, workers are migrating from agriculture to other sectors which is leading to unavailability of sufficient manpower in farm and also enhancing the labor wages. In this situation, farmers are required to use big machines/machinery such as tractor, thresher, combine

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harvester etc. for overall profitability. About 78% Indian farmers belong to small and marginal category who cannot afford to purchase all costly machinery for agricultural works. Consequently, these farmers hire the machines on payment basis either per hectare or hour basis, which is known as custom hiring. Due to increasing demands of agricultural machine, several custom hiring centers are being established by entrepreneurs, Government and non-government organizations. Calculation of operational cost as well as breakeven point is very essential to finalize the rate of custom hiring. In the absence of this information, customs hiring charges either under or over the optimum value. In both the cases, centers are running in loss because in one hand less return per hour and other hands less demand. The calculation of this information is not possible without an expert. Further, these cost calculation is regular exercise as because of frequent change in price of diesel, labor wages etc.

Many scientists have attempted to compute the cost of agricultural machineries in last decades. Beaton *et al*. [1] developed a quick and adaptable method for calculating the per unit cost to own and operate farm machinery. Abubakar *et al*. [2] provided a mathematical model for the repair and maintenance costs for the State of Nigeria but limited to the specific models of the tractor. Oluka [3] has also reported on the various factors that contribute to the ownership costs of farm tractors and the various techniques of estimating tractor costs in Nigeria under three different management systems. Khatibi and Jawawi [4] illustrated several existing methods for software cost estimation and discussed their aspects. Popovic [5] managed agricultural company through monitoring total cost of maintenance for tractor. Similarly, Todorovic [6] also worked on economically justified amount of investment in purchase of harvester at family farms. These works are basically region specific and none of the work is found for Indian condition.

Keeping these facts in mind, a study was formulated to develop a user friendly computer program for calculating the operational cost as well as breakeven analysis of agricultural machines.

THEORETICAL CONSIDERATIONS

Fixed Cost. Ownership costs are independent of use and are often called as fixed costs. It includes depreciation on equipment, interest, taxes and general overhead expenses. These costs are mathematically calculated [7] which are discussed in following sub-sections.

Depreciation means a loss in the value of a machine due to time and use. Often, it is the largest of all among fixed costs. Depreciation can be calculated in different ways, however Straight-line method is simple and easiest which is given by:

$$D = \frac{P - S}{L \times H} \tag{1}$$

where:

D [₹·h^{-1}] - depreciation cost,
P [₹] - purchase price of the machine,
S [₹] - salvage value which is an estimate of the sale value of the machine at the end of its economic life. S = 10% of purchase price.

L [years] - useful life of machine,
H [h·year^{-1}] - working hour per year.

A large expense item for agricultural machinery is interest. Interest rates vary but usually will be in the range of 9 to 12%. The following formula is used for calculating the interest:

$$I = \frac{P+S}{2 \times H} \times \frac{i}{100} \tag{2}$$

where:
I [₹·h^{-1}] - interest,
i [%·year^{-1}] - rate of interest,

Insurance is necessary against the risk of accident or disaster and is obtained from the following equation:

$$In = \frac{P \times rp}{H} \tag{3}$$

where:
In [₹·h^{-1}] - annual insurance fee,
r_p [fraction] - premium rate.

Tax is expressed in terms of rate to initial cost and approximately 0.5% to 1% is taken into account. Generally yearly taxation and its sum are calculated as follows:

$$Tx = \frac{P \times rtax}{H} \tag{4}$$

where:
Tx [₹·h^{-1}] - annual taxes,
rtax [fraction] - tax rate.

Housing expense will be obtained from the following equation:

$$h = \frac{P \times rgc}{H} \tag{5}$$

where:
h [₹·h^{-1}] - annual garage cost,
rgc [fraction] - garage cost rate.

The total fixed cost of equipment is calculated by adding the depreciation cost, interest, housing, insurance and tax.

$$F = D + I + In + Tx + h \tag{6}$$

Variable cost. Costs for operation vary directly with the use are termed as variable cost which has the relation to the volume of output. This includes the fuel, lubricating, wages, and repair and maintenance cost which are calculated (Hunt, 2013 and IS: 9164-1979) as follows:

$$Fl = FC \times FR \tag{7}$$

where:
Fl [₹·h^{-1}] - fuel cost,
FC [l·h^{-1}] - fuel consumption,
FR [₹·h^{-1}] - rate of fuel.

Surveys indicate that total lubrication costs on most farms average about 15% of fuel costs and hence can be estimated by multiplying the fuel cost by 0.15.

Repair and maintenance expenditures are taken into account as it is necessary to keep the machine functional. This cost is typically variable which is directly related to the use of the machine. As per IS: 9164 (1979), the first year repair and maintenance cost of tractor is 3.2% of initial cost, however, in 10^{th} year it is 14.5%. Therefore, average repair and maintenance cost may be assumed at 6% of initial capital cost of purchase per year.

Labor cost is also an important consideration in comparing ownership to custom hiring. Actual hours of labor usually exceed field machine by 10 to 20% because of travel and the time required lubricating and servicing machines. Consequently labor costs can be estimated by multiplying the labor wage rate by 1.1 or 1.2 times.

The total operating cost is the summation of fuel, lubrication, repair and maintenance, and labor costs. And hence total cost of operation is the total fixed cost and total variable cost.

Cost Calculation on Hectare Basis. The field capacity of a farm machine is the rate at which it performs its primary function, i.e., the number of hectare that can be covered per hour. The theoretical field capacity can be defined as:

$$FC = \frac{W \times V}{10} \tag{8}$$

where:
FC [ha·h^{-1}] - field capacity,
W [m] - width of operation,
V [km·h^{-1}] - velocity of operation.

Machinery cost on the basis of hectare can be calculated as:

Machinery cost (₹·ha^{-1}) = Machinery cost (₹·h^{-1}) / Actual field capacity (ha·h^{-1}) (9)

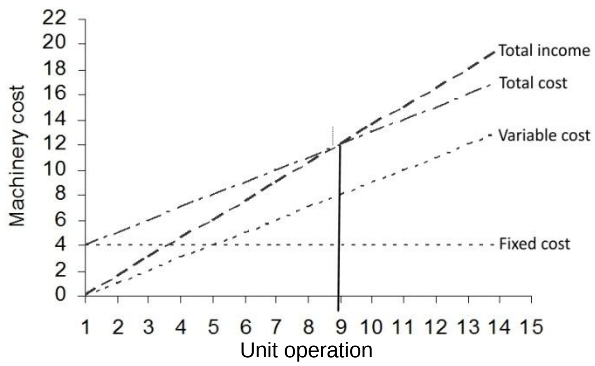

Figure 1. Breakeven analysis

Breakeven Analysis. Breakeven analysis computes the volume of operation at a given price necessary to cover all costs. The breakeven point is the intersection of the total cost line and the total income line (Fig.1). The total income line is the gross value of the output. A vertical line down from this point shows the level of operation necessary to cover all costs. Operation greater than this level generates positive revenue; losses are incurred at lower levels of operation.

Mathematically, the breakeven point is calculated with the following formula:

$$BEP = F / (C - V) \qquad (10)$$

where:

BEP [h·year^{-1}] - breakeven point,
F [₹·year^{-1}] - total fixed costs,
V [₹·h^{-1}] - variable costs per unit of operation,
C [₹·h^{-1}] - custom rate.

MATERIAL AND METHODS

Input Parameters. The input parameters for the developed computer program are mainly divided in two parts, namely power source input and implement input. The power source inputs include initial cost, life of machine, working hour per year, interest rate, taxes, housing rate, fuel consumption, fuel cost, and labor charges. Similarly, the inputs for implement are initial cost, implement life and working hour per year. The program window for input parameter is shown in Fig. 2. For breakeven analysis, a separate input is created which is shown in Fig. 3. The flow chart of the developed program is shown in the Fig. 4.

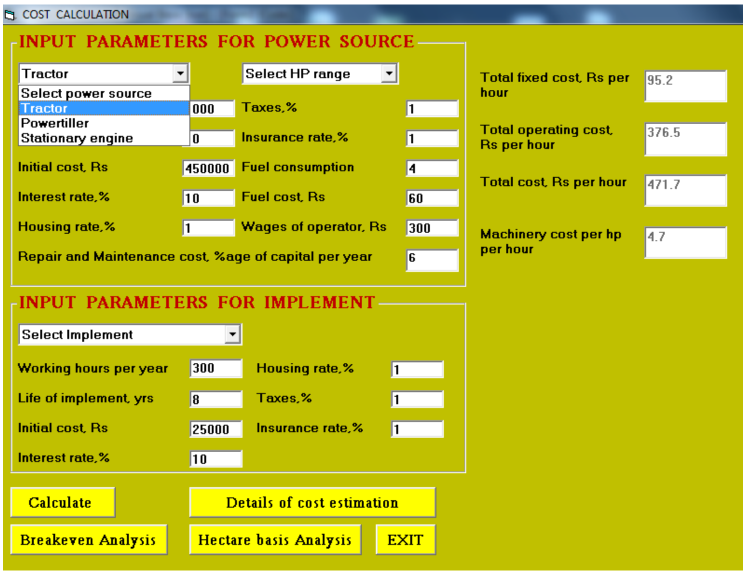

Figure 2. Program window for the input parameters

Output Parameters. The outputs of the program are mainly cost of operation on hour and hectare basis including interest, housing, taxes, insurance, fuel, lubrication, and wages cost for power source and implement separately. The output program window is shown in Fig. 5.

Figure 3. Program window for the breakeven analysis

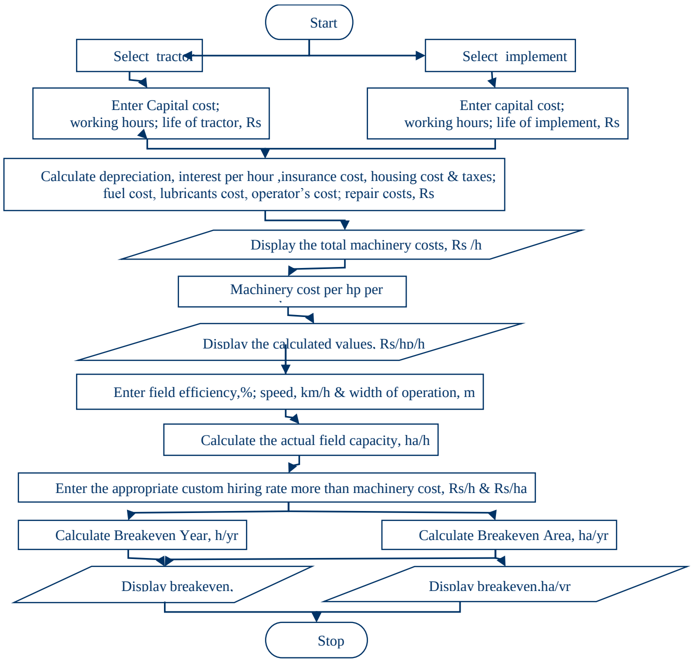

Figure 4. Flow chart of the developed program

Figure 5. Program window for the output parameters

RESULTS AND DISCUSSION

General Outputs of Software. The developed computer program was operated for three different combinations which are tractor with mould board plough, power tiller with rotavator and stationary engine with thresher. The input parameters for these combinations are given in Table 1. The software output for these runs is given in Table 2. Table indicates that the developed program is capable of calculating all components of fixed and operating cost of power source as well as for implement.

Table 1. Input parameters

Input parameters	Tractor with MB plough		Power tiller with rotavator		Stationary engine with thresher	
	Tractor	Plough	Power tiller	Rotavator	Engine	Thresher
Initial cost [₹]	400000	20000	150000	10000	30000	10000
Power [kW]	26	0	8.94	0	3.7	0
Working [hour·year^{-1}]	1000	300	800	300	1000	300
Life [years]	12	8	10	8	10	8
Fuel consumption [l·h^{-1}]	4		2		1	
Insurance, Housing and Taxes [%]	1 each					
Interest rate [%]	10					
Wages [₹·day^{-1}]	300					
Fuel cost [₹·l^{-1}]	50					

Table 2. Output parameters

Output parameters	Tractor with MB plough		Power tiller with rotavator		Stationary engine with thresher	
	Tractor	Plough	Power tiller	Rotavator	Engine	Thresher
Depreciation [₹·h^{-1}]	30	7.5	16.9	3.8	1.8	3.8
Interest [₹·h^{-1}]	22	3.7	10.3	1.8	1.1	1.8
Housing, Insurance and Taxes [₹·h^{-1}]	12	2.1	5.4	0.9	0.6	0.9
Fixed Cost [₹·h^{-1}]	64	13.2	32.8	6.6	3.5	6.6
Fuel Cost [₹·h^{-1}]	200.0		100.0		50.0	
Operator's wages [₹·h^{-1}]	37.5		37.5		37.5	
Lubricating Cost [₹·h^{-1}]	60.0		30.0		15.0	
Repair and Maintenance Cost [₹·h^{-1}]	24.0		9.0		1.2	
Total Operating Cost [₹·h^{-1}]	321.5		176.5		103.7	
Total Fixed Cost [₹·h^{-1}]	77.2		39.4		10.1	
Machinery Cost [₹·kW^{-1}·h^{-1}]	15.3		24.1		30.7	

Effect of Initial Cost on Machinery Cost. The developed program was run for different initial cost of tractor with plough of 30-50 HP range to calculate various costs which is given in Fig. 6. From the figure, it is evident that fixed cost and total cost increases significantly with increase of initial cost of tractor. However, variable cost increases marginally with the increase of initial cost. The variable cost mainly depends upon fuel, lubricating and labor costs which are independent of variable cost. The repair and maintenance is the only variable cost which depends on initial cost of tractor.

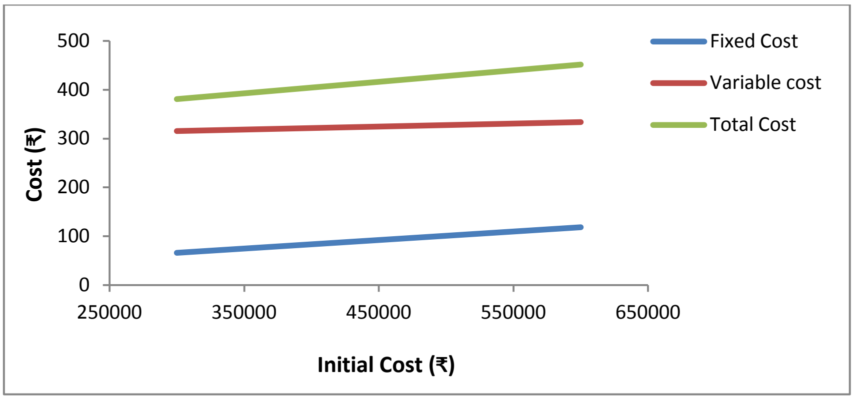

Figure 6. Relationship between initial cost and machinery cost

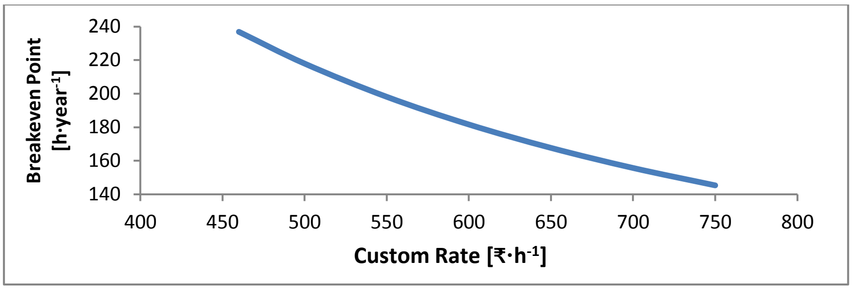

Figure 7. Relationship between custom hiring and BEP on hour basis

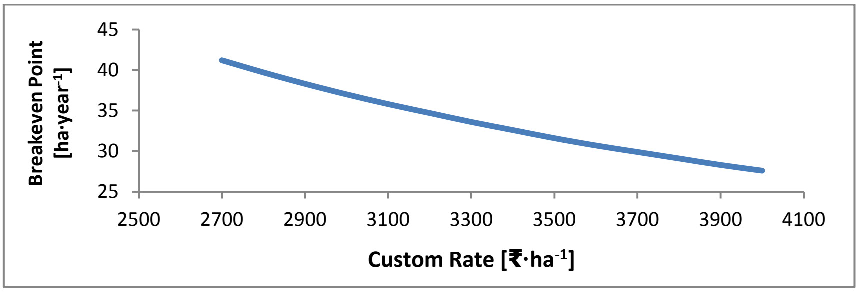

Figure 8. Relationship between custom hiring and BEP on hectare basis

Effect of Custom Hiring Rate on Breakeven Point. The effect of hour basis and hectare basis custom hiring rate at the breakeven point for a tractor is shown in Fig. 7 and Fig. 8, respectively. It clearly indicates that as custom hiring rate increases breakeven point decreases drastically for both the case either hectare basis or hour basis. For an example, if the custom hiring rate is fixed at the rate of *Rs* 550 per hour, it means it has to operate minimum 200 hours per year to be no profit and no loss. More than 200 hours per year there will be give profit.

CONCLUSIONS

The developed software is capable to calculate the cost of operation in Rupees per hour and in Rupees/hectare of different combinations of power sources and implements. Increase in cost of operation was observed with the increase in initial cost of tractor. The breakeven point decreases with the increase of custom hiring rate for tractor. This program can be a useful tool for suggesting the farmers in purchasing a machine as well as in deciding the custom hiring rates, profit and loss. This can also help to entrepreneurs who are engaged in custom hiring services to decide the hiring rate of different machinery on the basis of breakeven analysis.

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RAČUNARSKI PROGRAM ZA PROCENU TROŠKOVA POLJOPRIVREDNIH MAŠINA

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Sažetak: Kompjuterski program prilagođen korisniku je razvijen u Visual Basic okruženju da odredi sve tipove troškova mašina po času i hektaru. Program takođe omogućuje izračunavanje oblasti izjednačenja i vreme upotrebe mašina do povraćaja investicije. Ulazni parametric razvijenog programa su uglavnom početna cena, radni vek mašine, kamatna stopa, troškovi goriva, troškovi rada itd, za pogonske mašine i priključke. Ukupni troškovi se izračunavaju u dve grupe, fiksni i varijabilni troškovi. Fiksni troškovi se sastoje od depresijacije, kamate, poreza, smeštaja i osiguranja, dok varijabilni troškovi uključuju gorivo, mazivo, plate, popravke i održavanje. Razvijeni program uspešno izračunava troškove rada po času rada i po hektaru, za agregate različitih pogonskih i priključnih mašina. Analiza bilansa svakog agregata takođe može da se izvede. Ovaj program može da bude korisno sredstvo za preporuke farmerima pri kupovini mašina, pri određivanju cene iznajmljivanja i sl. Ovo takođe može da pomogne preduzimačima u servisima da odrede cene iznajmljivanja različitih mašina na osnovu analize bilansa.

Ključne reči*: troškovi rada, tačka izjednačenja, računarski program*

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MULTIFUEL POWER SUPPLY SYSTEM OF THE DIESEL ENGINE

Yury Kuznetsov[*], Yury Ryzhov, Alexey Kurochkin, Yulia Mikhaylova, Michael Mikhaylov

Orel State Agrarian University, Orel, the Russian Federation

Abstract: The design of the fuel system of the tractor diesel with the multistage heating, allowing to apply pure rapeseed oil as fuel in the diesel engine is described in the article.

Key words*: fuel, rapeseed oil, kinematic viscosity, fuel system, multistage heating*.

INTRODUCTION

Despite the development of new deposits of traditional energy sources, the question of their alternatives is extremely sharp. The reason for it is the fact that natural resources are limited, the prices for traditional energy sources constantly increase while the ecological situation on the planet gets worse.

The researches in the field of alternative and renewable fuels have been the prerogative of the energy and resource saving programs of many countries for a long time [6]. Many scientists of world-wide reputation achieved good results in the sphere of alternative energy sources. Data released in the sphere of atomic energy, solar energy, the usage of wind power generators and tidal energy of seas and oceans, as well as the application of biofuels revealed the positive points of alternative power-engineering, defined tasks and the ways of their solutions. Inspite of high variability of alternative power-engineering, the majority of scientific works with positive results won’t get wide manufacturing application in the nearest future for many reasons. Therefore, many European scientists and engineers think that “atom”, “hydrogen” and recuperative system will be applied in manufacturing only in 40-50 years. This time will take a

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transitional period, when biofuel will be used as a fuel for already existing combustion engine models [8]. By now biofuel gained trust and confidence of many countries. It is used in its pure state (alcohols replacing gasoline; biodiesel replacing traditional mineral diesel fuel; biogas in gas generator units) as mixtures with mineral fuels (*E5, E15, E80, E85, B10, B20*, etc.) and as a fuel additives [7,8].

In the context of agricultural enterprises the most suitable alternative for diesel fuel nowadays is bleached RO, meeting the requirements of the German standard *V 51605*. The use of pure RO as a fuel for diesel engines results in the following negative effects: loss of power, increased fuel consumption, shortened life of the fuel equipment, impair starting in cold weather, increased incrustration and lacquer formation, etc. [1,2].

The presence of negative moments in the operation of diesel engines due to *RO*, is primarily connected with the increased values of the kinematic viscosity compared to diesel fuel (*DF*). In terms of agricultural enterprises heating is the most effective way to reduce the viscosity of the pure *RO* and its mixtures with diesel fuel with a high content of *RO*.

Based on the temperature characteristics and the seasonal field work, we investigated the dependence of the kinematic viscosity of the pure *RO* and its mixtures with diesel fuel on the temperature and the content of the *RO* in the mixture with diesel fuel.

As the RO we used a sample obtained by hot pressing followed by filtration settling of these breeds of rape: *Northerner, Salsa, Ahat, Luned, Rohan, Krauser, Solar KL, Mobil KL, Lighthouse, Zorn, Proxima, Capital, Leader, Winner, Sfint* and *Heros*. The *DF* applied in the research met the requirements of *GOST R 52368 - 2005* "The National Standard of the Russian Federation". Diesel fuel Euro. Specifications were in line with quality D, class 2.

In the process of research we determined the kinematic viscosity of pure *RO*, as well as its mixtures with *DF*, where *DF* content was gradually increased to 100% in 10% increments. The temperature range of viscosity determination was from 20^0 to 90^0 C. The determination of kinematic viscosity was carried out according to *GOST 33-2000* "Oil products. Transparent and opaque liquids. Determination of kinematic viscosity and calculation of dynamic viscosity". The mixture heating was conducted in a water-bath, the instruments for measuring kinematic viscosity were capillary viscometers type *IWF*-1m. The experimental methods were treated with the methods of interpolation and extrapolation.

RESULTS AND DISCUSSION

The determination of dependences of kinematic viscosity on temperature and composition of fuel mix (Figs. 1 and 2) was the result of the researches, first of all.

The more *RO* the mixture contains, the lower the content of harmful substances in the exhaust gases and the fuel price and the higher energy independence of the enterprise (on condition of intrafarm *RO* production), however the kinematic viscosity of the mixture is higher. At a temperature of 0°C the *RO* viscosity is by 36,67 … 22,003 times higher than of the *DF*. Gradual temperature increase of the fuel mixtures to 40°C gives sharp decrease in viscosity. For example, at pure *RO* the kinematic viscosity of the testing sample while heating to 40°C decreases by 4,5 times in comparison with value at

0°C and attains 24,503 cSt. Further temperature increase entailed to slower decrease in viscosity. And at a temperature of 90°C the viscosity of pure *RO* attains the value of about 7,384 cSt that allows to minimize the above-mentioned negative moments at operation of diesel engines of a domestic production on this fuel.

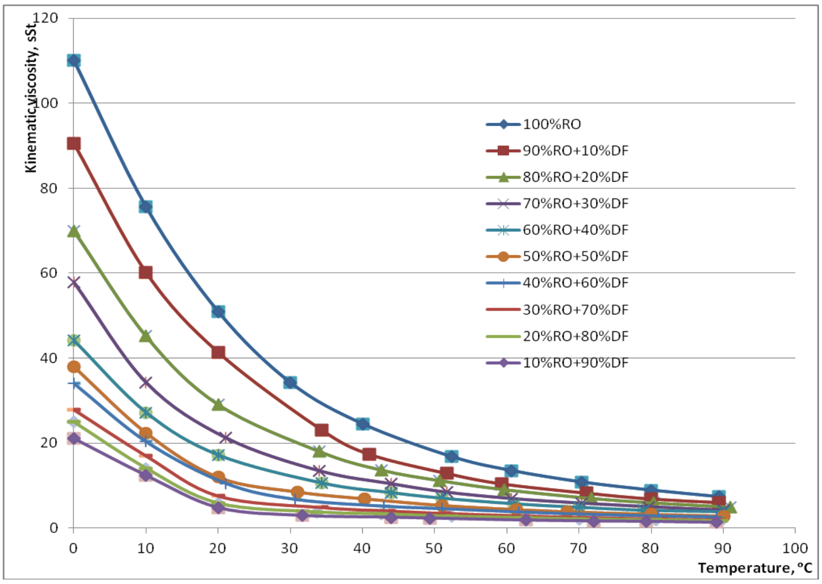

Figure 1. The dependence of the fuel mixture kinematic viscosity on temperature

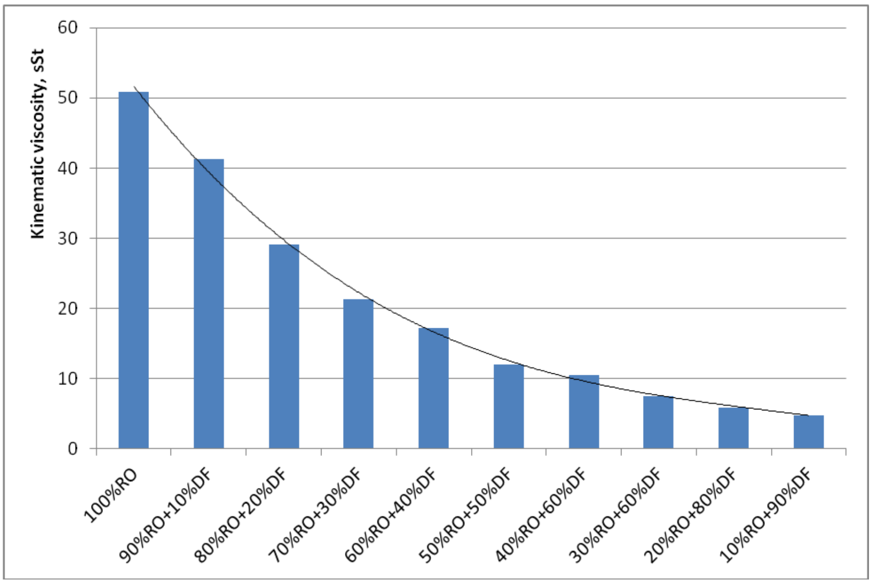

Figure 2. The dependence of the fuel mixture kinematic viscosity on its content at a temperature of 20°C

For temperature range from 0 to 40°C for all the fuel mixtures sharp decrease in viscosity is typical. The raised content of *DF* in them (from 40% and more) also gives decrease in fuel mix viscosity.

In general the analysis of the results of researches with testing samples confirmed the possibility of use as fuel for diesel engines fuel mixtures containing less than 30% of *RO* at an ambient temperature 20°C. However, the use of fuel mixtures with the low content of *RO* is ineffective from the point of view of ecology and economy, and the use of fuel mixtures with the high content of *RO* without heating is impossible. The heating of *RO* up to the temperature of 700 … 90°C provides decrease in kinematic viscosity, increase in the fineness of injection, reduce of the flame length, i.e. promotes the improvement of the carburetion and combustion processes [3].

We offered a design (Fig. 3) of a dual-fuel system of the tractor diesel with *RO* multistage heating, which provides the use of vegetable-based oil. It contains a mineral fuel tank 1, a vegetable-based fuel tank 2, where are a heat exchanger 6 and a temperature sensor 21 of the vegetable-based fuel set, mineral fuel intake line 3, vegetable-based fuel intake line 7, hydraulic directional valve 11 located in front of the fuel fine filter 12, ultrasonic filter 13 located in front of the injection pump 14, electric heaters 16 located in front of the nozzles 15, a fuel drain line 17 from the nozzles 15 and a fuel drain line 18 from the injection pump 14, an electronic control unit (*ECU*) 19, a position sensor 20 of the fuel pump rail, located in the fuel pump regulator body. Line 3 of the intake mineral fuels contains first -stage fuel filter 4 and an electric booster pump 5 with a pressure relief valve. Line 7 of the vegetable-based fuel intake, in its turn, contains first-stage fuel filter 8, fuel pump 9 of a standard power supply system and the *PTC* thermistor heater 10. [9]

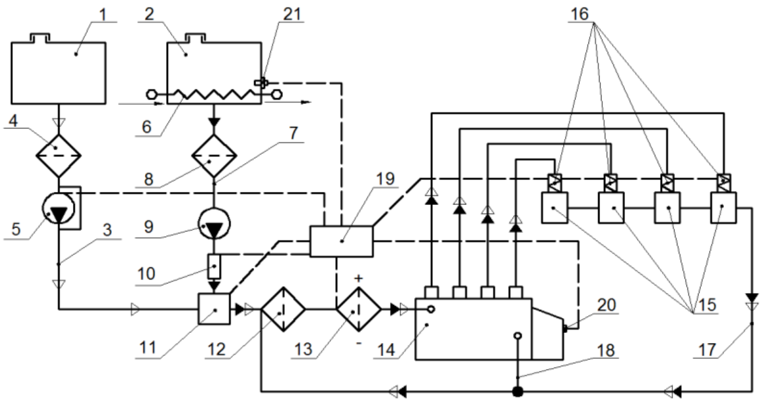

Figure 3. The diagram of a multifuel power supply system of the diesel engine

The first heating stage includes heat exchanger 6, connected to the engine cooling system and heating the vegetable-based oil in tank 2 to the temperature of 20 ... 30°C, that ensures its pumpability even at low ambient temperatures.

The second step of heating is one of the most problem parts of the fuel system which includes booster pump, fine filter and high pressure fuel pump (a fuel site of low pressure). The reason for it is that the standard fine filter of *DF* possesses some resistance of pumpability and isn't intended for filtering more viscous, in comparison with *DF*, vegetable and mineral mixtures. Therefore standard booster pumps combined with standard fuel fine filters don't provide necessary productivity. The heater design 10 (Fig. 3) offered by us allows to solve this problem with minimum changes in the standard fuel system. Application of this heater will allow to increase the efficiency of a heat-transfer process, and, therefore, to apply *RO* and its mixtures with *DF* as fuel to diesel engines. A site of low pressure, in front of the fuel fine filter, is a possible installation site.

The heater consists of the case 1 (Fig. 4) in the form of the union made of dielectric material. It is possible to use textolite as dielectric material which has also good mechanical properties. Posistors 4 are fixed in the case 1 perpendicular to its axis on the forming spiral with an equal step. In their form posistors 4 (Fig. 5) represent a circle segment, equal, for example to 2/3 of a circle. Careful mixing of liquid while heating and consequently more effective heat-transfer process are provided thanks to a special form of posistors 4 and their arrangement in the case of heater 1. Posistors 4 are powered from a vehicle’s lighter socket by means of the current-carrying plates 2, located in the case 1. To simplify the assembly process the posistor 4 and the current-carrying plates 2 can represent a one-piece unit. Besides, the current-carrying plates 2 serve as fixing elements for posistors 4. The design allows to unite analogous poles of the current-carrying plates 2. The posistors 4 are powered in-parallel; it also increases the reliability of the heater. The case 1 is encapsulated by the insulating material 3, epoxy resin for example. Besides, the use of epoxy allows to increase the structural rigidity.

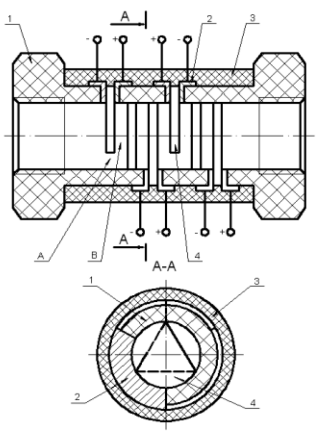

Figure 4. The arrangement drawing of a fuel heater

The form of posistors as a segment of a circle provides the greatest surface contact area with fuel, and their arrangement in the case stands for the effective mixing of the fuel in the heater.

The fuel heater works in the following way.

Before the start-up of the engine the heater is connected to the current source, for example to the vehicle battery. When the current flows through the posistors, they heat up and give their warmth to the fuel. When the fuel is heated to the set temperature, which is the characteristics of the posistors, they "are locked", in other words the resistance of the posistors increases at least in one thousand times that reduces current flowing through the posistors and the serially connected lamp (it isn't shown in the figure). After the lamp is switched of, the engine starts.

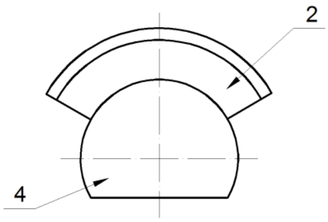

Figure 5. The drawing of the form of a posistor

The fuel, passing channel *A*, gets into a cavity *B*, hitting a posistor wall, swirls and washes the walls of the posistors, forming a cavity, then through the next channel it gets into the next cavity. Thus, consistently passing from one cavity to another, the mode of effective passive mixing is reported to the fuel that in its turn allows to increase the heat-transfer process efficiency.

The third stage of heating is realized as electric heaters 16 mounted directly in front of the nozzles 15. The vegetable-based oil at this stage is heated to a temperature of 80 ... 90°C. Electric heaters 16 contain posistors, which stand for control units, so they are self-regulated. The heating of the vegetable-based oil to a temperature of 80 ... 90°C during injection ensures less flame length and a finer spray compared with lower preheating temperatures.

The dual-fuel system of a tractor diesel with multistage heating operates in the following way:

The start and warming up of the engine is carried out on diesel fuel. At the same time it is supplied by the electric boost pump 5 from the tank through the first- stage fuel filter 4, hydraulic directional valve 11, the fine filter and ultrasonic filter 13 in the high pressure pump 14. Then the diesel fuel through the electric heaters 16 is supplied to the nozzles 15. When the engine is warming up and during the operation with diesel fuel ultrasonic filter 13 and electrical heaters 16 are switched off. The excess of diesel fuel from the nozzles 15 and the fuel pump 14 through the drain lines 17 and 18 are supplied to the fine filter 12.

When heating and during the engine operation the coolant of its system circulates through the heat exchanger 6. Once the temperature of the vegetable-based oil reaches the level of 20 ... 30°C in the tank 2 of the electric control unit 19, perceiving this option by the temperature sensor 21, switches the hydraulic directional valve11 in the position of supplying vegetable-based oil and also starts the work of heaters 10 and 16 as well as ultrasonic filter 13. The main function of the ultrasonic filter 13 is further reduction of the kinematic viscosity of the vegetable-based oil.

After switching the hydraulic directional valve 11 in the position of supplying vegetable-based oil, the oil supply stops because the ECU 19 turns the electric boost pump 5 off (the ECU 19 gives signal for the spool of the hydraulic directional valve to stop the diesel fuel supply into the system), the fuel boost pump 9 of the standard power system, delivers warmed to 20 ... 30° C vegetable-based oil from tank 2 through a first-stage fuel filter 8 into the posistor heater 10 where it is heated to 60 ... 70° C. Then the oil is sent by the hydraulic directional valve 11 through the fine filter 12 in an ultrasonic fuel filter 13, where the vegetable-based oil is subjected to cavitation treatment, whereby its viscosity is further reduced, and it is supplied into the high pressure pump 14 and then to the electric heaters 16, where it is heated up to 80 ... 90° C and the injection nozzles 15 spray it into the combustion chamber. The excess of vegetable-based oil from the nozzles 15 and the high pressure pump 14 through the lines 17 and 18 are sent to the fine filter 12.

Thanks to the use of *PTC* thermistor in the heaters 10 and 16, the latter automatically maintain the temperature of vegetable-based oil in the fuel system. In the *PTC* heater 10, they have two functions: they are heating elements and at the same time they maintain the oil temperature in the range of 60 ... 70°C. The heating elements in the electric heaters 16 are spirals, while posistors serve as elements supporting the temperature in the range of 80 ... 90°C.

At steady state conditions of the minimum stable speed and regimes of part-load engine (to 35%), the latter runs on diesel fuel [4]. When working on the above-mentioned modes the rail position sensor 20 of the fuel pump sends a signal to the *ECU* 19, which puts the system on diesel fuel. The *ECU* 19, used in the dual-fuel system, allows a person to switch from one fuel to another one manually[10].

Before stopping the engine, the fuel system is converted to pure diesel fuel and the engine should run on it for about 5 minutes (depending on operating mode).

The usage of the offered dual-fuel system of the tractor diesel engine will allow to apply vegetable-based oil as a fuel in cold season and improve the overall efficiency of the engine on this type of fuel.

CONCLUSIONS

1. The dependences of kinematic viscosity on temperature and content of fuel mix are defined.
2. The existing recommendations about application of the fuel mixtures on the basis of vegetable-based oils are added.
3. The devices allowing to apply biofuel on the basis of RO as fuel to diesel engines are developed.

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VIŠEGORIVNI POGONSKI SISTEM DIZEL MOTORA

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Sažetak: U radu je opisana konstrukcija sistema za napajanje gorivom traktorskog dizel motora sa višestepenim grejanjem, koji omogućuje primenu čistog uja uljane repice kao goriva za dizel motor.

Ključne reči*: gorivo, ulje uljane repice, kinematička viskoznost, system za napajanje gorivom, višestepeno grejanje*

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DESIGN OF FLOOD AND DRAIN VERTICAL HYDROPONIC SYSTEM

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***Abstract**:* The study was conducted by installing the Flood and Drain Vertical Hydroponic System for cultivating Chinese leafy vegetable Pak-choi (var. Choko) of family Brassicaceae. The system was designed in the department of Irrigation and Drainage Engineering, K. K. Wagh College of Agricultural Engineering and Technology with the help of *CATIA* software. The sowing of 112 seeds of Pak-choi was done in perforated net pots containing media of coco-pit (8% *N : P : K* treated) and vermiculite in 1:1 proportion. Irrigation was applied to the crop by deep flow technique through beds. The average *pH* readings before and after each irrigation was 6.40 and 6.76 and the average values of *EC* before and after each irrigation was 0.79 $mmhos \cdot cm^{-1}$ and 0.97 $mmhos \cdot cm^{-1}$, respectively. Also the average moisture content of media before and after each irrigation was noted, which was 18% and 71% respectively, available moisture content for complete growth of crop ranged from 46.73 to 57.05%. The water requirement of Pak-choi crop was 2.63 cm.

The fertilizer applied was 1.9 gm *N:P:K* for overall growth of crop. The harvesting of crop was done after 70 days from sowing and the yield of crop was 7 kg from 1.8 m^2 area. The total cost of system was estimated to be *Rs*.3400 /-. Highest germination of 96% was achieved with our hydroponic system, which was 26% more than germination percentage quoted by the manufacturing company of seeds. Yield of Pak-choi crop in hydroponic system was twice than the yield obtained from field conditions. Therefore, the Flood and Drain Vertical Hydroponic System designed gave 66% more cropping area than the open field.

Key words: *flood and drain vertical hydroponic system, pak-choi, irrigation*

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INTRODUCTION

With the advent of civilization, open field/soil-based agriculture is facing some major challenges, most importantly decrease in per capita land availability. In 1960 with 3 billion population over the World, per capita land was 0.5 ha but presently, with 6 billion people it is only 0.25 ha in 2013 and by 2050, it will reach at 0.16 ha. due to rapid urbanization and industrialization [4]. Also soil fertility status has attained a saturation level and productivity is not increasing further with increased level of fertilizer application. Besides, poor soil fertility in some of the cultivable areas, less chance of natural soil fertility build-up by microbes due to continuous cultivation, frequent drought conditions and unpredictability of climate and weather patterns, rise in temperature etc. Under such circumstances, in near future it will become impossible to feed the entire population using open field system of agricultural production only. To cope with these challenges naturally, soil-less culture is becoming more relevant in the present scenario. In soil-less culture, plants are raised without soil. Growing plant in solution culture is easier than soil culture because there is no need of soil, no soil born disease or pest, irrigation is less frequent in solution culture than in soil culture [3]. Roots are visible and root zone environment is easily monitored and controlled. Improved space and water conserving methods of food production under soil-less culture have shown some promising results all over the World.

Basically, there are five types of hydroponics systems and Flood and Drain system of hydroponics (also called Deep Flow Technique) is one of the hydroponics system that works by temporarily flooding the bed 2-3 cm deep with nutrient solution [2] that flows through 10 cm diameter PVC pipes to which plastic net pots with plants are fitted. The excess amount of nutrient solution is drained back into the reservoir. This action is normally done with a submerged pump. The plastic pots containing planting materials and their bottoms touch the nutrient solution that flows in the pipes. The PVC pipes may be arranged in one plane or in zigzag shape depending on the types of crops grown. This is a versatile system that can be used with a variety of growing mediums. The entire bed can be filled with pro-mix, vermiculite, gravel or coco-pit. Many people like to use individual pots filled with growing medium, this makes it easier to move plants around or even move them in or out of the system. Considering the advantages of hydroponics, it was proposed to design and fabricate flood and drain vertical hydroponic system.

MATERIAL AND METHODS

The system was designed in the department of Irrigation and Drainage Engineering, K. K. Wagh College of Agril. Engg. & Technology, Nashik with help of *CATIA* software as shown in Fig.1 to Fig.4. The Flood and Drain Vertical Hydroponic system was fabricated in the workshop of our College consisted of main components as shown in Tab.1.

Fabrication of flood and drain system. For fabrication of flood and drain system, initially the frame was fabricated, then on frame pipes were placed on hooks which were welded on frame with the help of spot welding. The following procedure was followed for fabrication of frame:

a) measuring and marking on material.
b) cutting of material with the help of power saw and hack saw.
c) welding of frame with the help of arc welding machine.
d) welding of hooks with spot welding.
e) coloring of the frame.

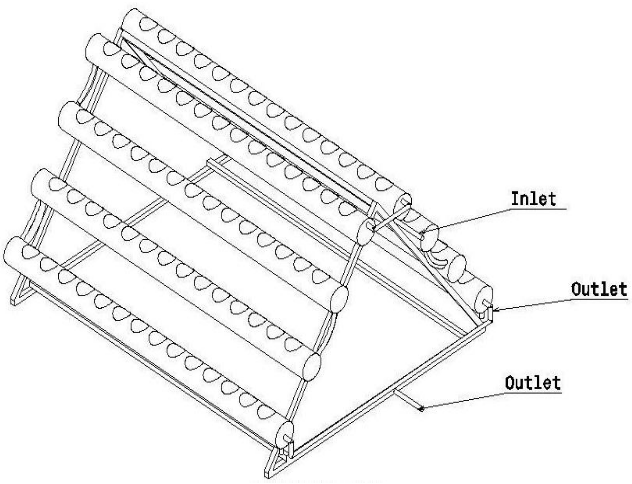

Figure 1. Isometric view

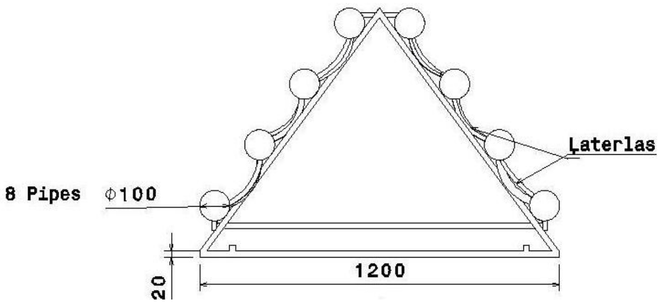

Figure 2. Side view

Table 1. Main components of flood and drain vertical hydroponic system

Material	*Size*	*Quantity*
PVC pipe	*10 cm diameter*	*40 ft*
CRC pipe	*2x2 cm*	*65 ft*
G.I Hooks	*10cm diameter*	*16 Nos.*
PVC End cap	*10 cm*	*16 Nos.*
LDPE lateral	*8 mm*	*12 ft*
Grommet takeoff	*8 mm*	*16 Nos.*
Net pot	*15 cm*	*112 Nos.*
Submersible pump	*2.5 m Head*	*1 Nos.*
Media	*Pro mix*	*16 kg*

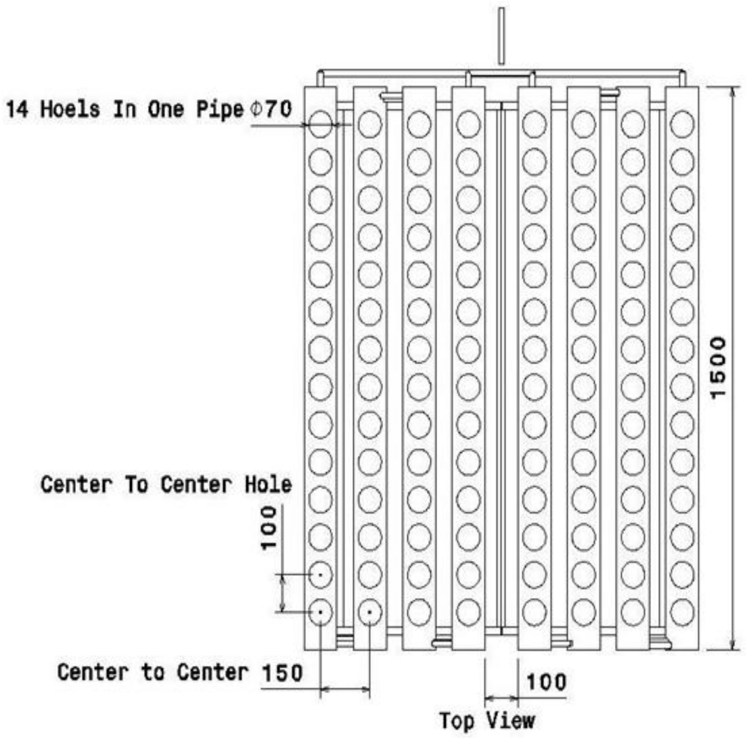

Figure 3. Top view

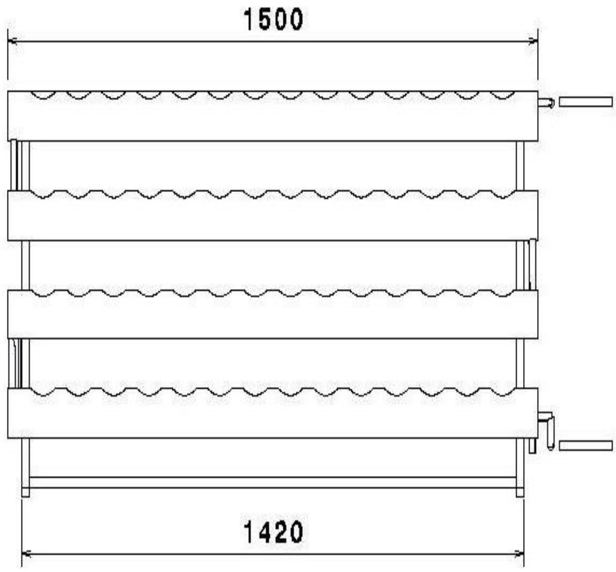

Figure.4 Front view

Preparation of bed and media. System beds were made of 4 inch *PVC* pipes which were sealed with end cap on both ends having 5ft length. Eight numbers of pipes were mounted on the frame. Each pipe bed contained 14 pot holding holes of 7 cm diameter and spaced at 10 cm distance from each other. Net pot was made up of plastic material of 7 cm diameter and 10.5 cm depth. Pot was perforated upto 3 cm height from its bottom.

Media consisted of composition of coco-pit (8% *N: P: K*) [5] and vermiculite in proportion of 1:1. Total mass of media used was 16 kg (coco-pit and vermiculite each 8 kg) to fill up 112 pots, each pot content 71.42 gm of media.

Sowing of seeds and irrigation. The sowing of Pak-choi chinese leafy vegetable (var. Choko) seeds of *Brassicaceae* family was done 2-3 cm deep in net pots on 23rd September 2014 with crop spacing was 10x15 cm. Total 112 seeds were sown in perforated net pots containing media.

First irrigation was provided immediately after sowing of seeds on 23rd September 2014 and then after every 15 days, irrigation was given to the crop. The amount of water applied was 20 liter per irrigation for 5 min. Before and after every irrigation, EC and pH readings of water sample were determined using standard procedures. The water requirement of crop was determined using soil moisture depletion studies by using the formula:

$$D = [(M.C\ after\ irrigation – M.C\ before\ irrigation)/100\ ] \times B.D \times d \qquad (1)$$

where:

D [cm] - water requirement of crop,
M.C. [%] - moisture content,
B.D. [$g \cdot cm^{-3}$] - bulk density,
D [cm] - root zone depth.

A submersible pump of 0.5 watt was used for lifting water, having 2.1 m head & discharge capacity of 1100 lph. *LDPE* lateral of 16 mm size was used having length 12 ft. for recirculating the irrigation water throughout the system. Total 16 joiners of 16 mm size made up of poly ethylene (PE) material were used. Water tank of capacity 35 litres was used for irrigation which was made up of plastic material.

Fertilizer application. On 13th October 2014, fertilizer grade 19:19 was mixed with water and applied to the crop. The fertilizer solution was prepared by adding 4 gm of fertilizer in 2 liters of water.

The media content 8% *N:P:K* and from 8 kg of coco-pit 213.33 gm of nitrogen, phosphorus and potassium each was obtained. From 8 kg of vermiculite, 160 gm of nitrogen, 120 gm of phosphorus and 80 gm of potassium was applied to crop. Also from fertilizer 19:19, 1.33 gm of phosphorus and potassium each was applied.

Cost estimation of flood and drain vertical hydroponic system. Cost of flood and drain vertical hydroponic system was estimated for 1.8 m^2 area (area of model). Operating cost is negligible because 0.5 watt pump was operated only for 5 min, for each irrigation.

RESULTS AND DISCUSSION

Germination of seeds occurred after 4 days from sowing. Germination percentage of seeds obtained with the present (Flood and Drain) system was 96%, which was 26% more [1] than the standard values mentioned on seed packet of the company (Tokita Seed India).

First irrigation was provided immediately after sowing seeds then after every 15 days irrigation was given to the crop. The amount of water applied was 20 litres per irrigation for 5 min. Actual water applied to the crop was 20 litres per 15 days of interval, 4 irrigations were provided to the plants through flood and drain system. Water applied to all the plants per day was 1.33 litre/day and per plant was 0.01199 litre/day. Hence total water applied to plant throughout its growth period was 80 litres. Water requirement of Pak-choi crop was 2.63 cm.

Table 2. PH and EC readings of water sample

Date	*Before Irrigation*		*After Irrigation*	
	pH	*EC (mmhos·cm^{-1})*	*pH*	*EC (mmhos·cm^{-1})*
23/09/2014	*6.36*	*0.78*	*6.70*	*0.91*
13/10/2014	*6.41*	*0.80*	*6.60*	*0.87*
04/11/2014	*6.40*	*0.80*	*6.90*	*1.1*
25/11/2015	*6.44*	*0.80*	*6.84*	*1.0*

Before and after every irrigation *EC* and *pH* readings of water sample were noted as shown in Tab. 2.

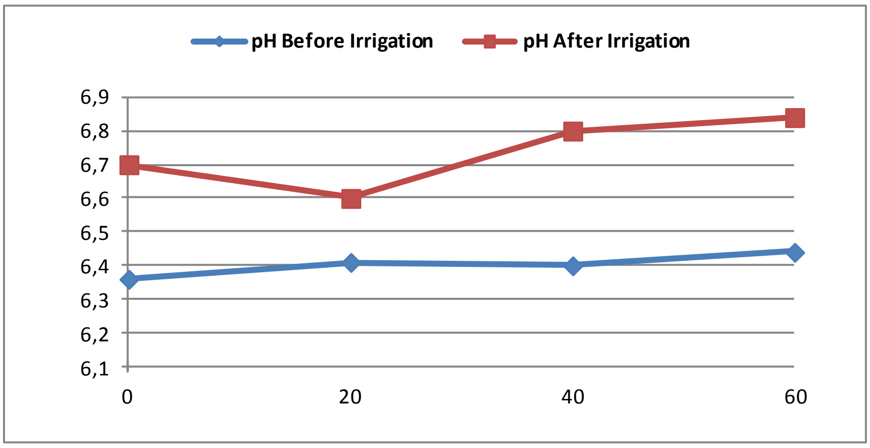

Figure 5. Variations in pH of water sample

The Fig. 5 shows variations in pH of water sample taken before and after irrigation. The pH values varied from 6.36 to 6.44 for water sample before irrigation and it ranged from 6.66 to 6.84 for water sample after irrigation. The variation in the *pH* values was very less and was also within permissible limit for specified crop. It was also observed that *pH* value of water after irrigation has increased due to passage of water from treated media (8% *N:P:K*). Optimum nutrients are available for growth of Pak-choi crop at *pH* value of 7 was reported by the website hydroponicexpress.com.

The Fig. 6 shows variations in *EC* values of water sample before and after irrigation. The EC values varied from 0.78 to 0.80 mmhos·cm^{-1} for water sample before irrigation and it ranged from 0.87 to 1 mmhos·cm^{-1} for water sample after irrigation. The variations in *EC* values were very less. It was also observed that the EC values increased after every irrigation which was due to passage of water from treated media (8% *N:P:K*).

Moisture content readings were taken at an interval of 20 days before and after irrigation as shown in Tab. 3.

The Fig. 7 shows the variations in moisture content of media. The moisture content of media was measured before & after each irrigation. The moisture content of media before irrigation was less and it was more after irrigation, which was due to application of water through the system. Media absorbed water during irrigation, resulting in increase in moisture content. The average available moisture content that was available to the crop throughout its growth period ranged from 46.73% to 57.05%.

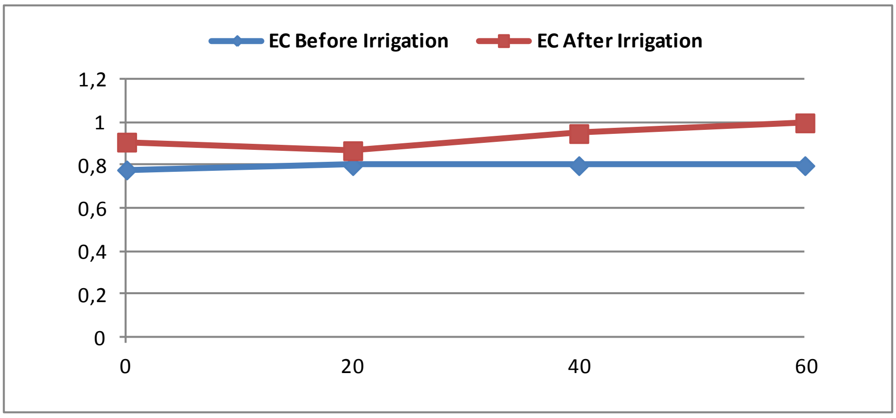

Figure 6. Variations in EC of water sample

Table 3. Moisture content of media before and after irrigation

Date	*Moisture Content (%)*	
	Before Irrigation	*After Irrigation*
23/09/2014	*25*	*71.73*
13/10/2014	*16*	*73.05*
04/11/2014	*18.5*	*72.00*
25/11/2014	*15*	*68.00*

The actual fertilizer applied to Pak-choi crop was 1.9 gm/plant (N:P:K). Also the total fertilizer applied to total number (112 Nos.) of Pak-choi crop planted was 213.33 gm of N:P:K each.

The crop growth after sowing was observed. The crop had two leaves with an average height of 3 cm initially after 7 days from sowing and prior to harvesting the crop had 8 leaves with an average height of 25 cm 60 days after sowing as shown in Fig 8.

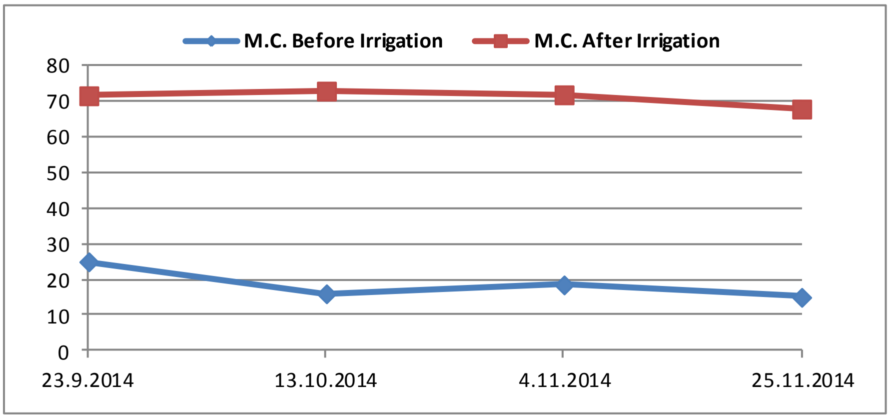

Figure.7. Variations in moisture content of media

Figure 8. Growth of Pak-choi crop after 60 days from sowing

The crop was harvested after 70 days from sowing. The yield of Pak-choi crop obtained was 7 kg from 1.8 m^2 area. Thus, Flood and Drain Vertical Hydroponic System designed by us gave 66% more cropping area than on the field. The estimated cost of the Flood and Drain Vertical Hydroponic system was Rs. 3400/- .

CONCLUSIONS

The Flood and Drain Vertical Hydroponic System was designed and installed successfully. Highest germination percentage was achieved i.e. 96% with our designed hydroponic system. The taste and flavour of crop grown in flood & drain vertical hydroponics system is good as compared to crop grown in soil. No chance of transfer of soil borne diseases to crop. Yield of Pak-choi crop in hydroponic system was twice than the yield obtained from field conditions also system gives 66% more cropping area than the area required on the field.

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KONSTRUKCIJA PRELIVNOG I ODLIVNOG VERTIKALNOG HIDROPONIČKOG SISTEMA

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Sažetak: Istraživanje je izvedeno na instalaciji prelivnog i odlivnog hidroponičkog sistema za uzgoj kineskog kupusa (var. Choko) iz familije *Brassicaceae*. Sistem je konstruisan u Institutu za navodnjavanje i odvodnjavanje Fakulteta za poljoprivrednu tehniku i tehnologiju K. K. Wagh, pomoću programa *CATIA*. 112 semena kupusa je posejano u perforirana gnezda sa podlogom od kokosovih vlakana (tertian sa 8% *N:P:K*) i vermikulita u odnosu 1:1. Biljke su navodnjavane tehnikom dubokog toka kroz podloge. Srednje vrednosti *pH* pre i posle svakog navodnjavanja iznosile su 6.40 i 6.76, a srednje vrednosti *EC* pre i posle svakog navodnjavanja iznosile su 0.79 $mmhos \cdot cm^{-1}$ i 0.97 $mmhos \cdot cm^{-1}$, redom. Srednji sadržaj vlage u podlozi pre i posle svakog navodnjavanja iznosio je 18% i 71%, redom, a dostupna vlaga za potpuni porast biljaka varirala je od 46.73% do 57.05%. Zahtev biljaka za vodom iznosio je 2.63 cm.

Za ukupni porast biljaka primenjeno je 1.9 gm *N:P:K* đubriva. Biljke su ubrane 70 dana posle setve, a prinos je iznosio 7 kg sa površine od 1.8 m^2. Ukupna cena sistema procenjena je na *Rs*.3400 /-. Najveća kliavost koja je postignuta ovim hidroponičkim sistemom bila je 96%, što je 26% više od procenta klijavosti koji garantuje proizvođač semena. Prinos kineskog kupusa u hidroponičkom sistemu bio je dvostruko veći od prinosa postignutog u poljskim uslovima.

Ključne reči: *prelivni i odlivni vertikalni hidroponični system, kineski kupus, navodnjavanje*

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EFFECT OF TEMPERATURE AND IMMERSION DURATION ON OSMOTIC DEHYDRATION OF ONION SLICE

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Abstract: Water loss, solid gain, weight loss and moisture content of osmotic dehydrated onion (*Allium cepa L.*) were studied. The effect of temperature and time to onion slices during osmotic dehydration for the onion slices were optimized using response surface methodology (*RSM*). Increase in process temperature and immersion duration increases the solid gain, water loss, weight loss and decrease in moisture content. Process temperature had non-significant effect on solid gain, as well as significant at 5% level significance on water loss, weight loss and moisture content. Optimized values of temperature and time were 42.08°C and 111.13 min, respectively.

Key words*: process temperature, immersion duration, osmotic dehydration, onion*

INTRODUCTION

Onion (*Allium cepa L.*) is an important spice and vegetable crop grown in all over world. Dehydrated bulb or onion powder is in great demand which reduces transportation cost and storage losses. The resulting product has generally better quality than the dried one without pretreatment. As bulk of onion is water (82–87%), reduction of moisture using suitable mechanical means prior to conventional hot air drying can be a simple technique to reduce moisture loading on dryer and hence the energy consumption. Also it is well known fact that each 1% reduction in feed moisture leads to 4% less dryer energy input [3, 15]. Effect of mechanical dewatering prior to hot air drying was investigated on drying time, specific energy consumption, flavor and color of dried product [7]. Osmotic dehydration of pork meat in molasses saved energy ranging from 89157 to 177092 kJ·kg^{-1} [19].

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The most important variable affecting the kinetics of mass transfer during osmotic dehydration is temperature. Increase in temperature of osmotic solution results in increases in water lose, whereas solid gain is less affected by temperature. Higher process temperatures seem to promote faster water loss through swelling and plasticizing of cell membranes, faster water diffusion within the product and better mass (water) transfer characteristics on the surface due to lower viscosity of the osmotic medium. At the same time solids diffusion within the product is also promoted by higher temperatures, only at different rates, mainly dictated by the size of the solute and concentration of the osmotic solution. Dehydration rates of apple slices increase with increase in osmotic pressure and temperature of solution [16].

Talaja Red onion of Sauratshtra Region of Gujarat have higher value for exporting as a row and dehydrated product in Middle East countries. There are about hundreds of dehydrated industry cluster in this region. The objective of this work was to study the osmotic dehydration on onion slice as a function of temperature and immersion time through response surface methodology (*RSM*) in order to identify process conditions for a high water loss at minimal solid uptakes (as an extensive solute uptake is undesirable and the product can no longer as marketed as 'natural') and to optimize the osmotic dehydration as a pre-treatment to further processing.

MATERIAL AND METHODS

The experiment mainly consists of experimental design, preparation of sample, determination of initial moisture content of onion slices, preparation of osmotic solution and osmotic dehydration process.

Preparation of sample and solution. The selected variety of summer onion was peeled and washed with water and unwanted material like dust, dirt, and surface adhering were removed. The onion bulbs were sliced with an electrical slicer of approximate 4 mm ± 0.5 mm thickness. Each slice was weigh and subsequently individually marked by using different color threads, the ratio of solute to onion slices was 7.5:1 w/w.

Measurement of initial moisture content. The moisture content of fresh as well as osmotically dehydrated onion samples was determined by using air oven method and calculated by using following equation [13].

$$Percent\ moisture\ content\ (db) = \frac{w_1 - w_2}{w_1} x100 \quad (1)$$

Osmotic dehydration process. 100 g onion slices of 4 mm thickness were immersed into a glass jar containing 750 g of concentrated osmotic solution. The glass jars containing immersed samples were kept at five different temperatures i.e., 22, 31, 40, 49 and 58°C. in the *B.O.D.* incubator (Patel Scientific Instrument, Ahmedabad) at five levels of immersion duration i.e., 30, 67.5, 105, 142.5 and 180 min. After completion of immersion duration, the onion slices were removed from the osmotic solution, slices rinsed with clean water to remove the osmotic solution adhered on the surface and then put on a blotting paper to remove surface moisture from the slices. The mass and moisture content of the samples were measured for determination of mass loss, water loss and solid gain.

Experimental design. The Design Expert 8.0.7.1 software was used in making the experimental design for chemical pretreatment prior to osmotic dehydration of onion slices. Response Surface Methodology (*RSM*) was used for designing the experiments. The quadratic model of Central Composite Rotatable Design (*CCRD*) was selected for making experimental design [4].

The effect of four independent variables viz. process temperature, immersion duration, salt concentration and sucrose concentration on water loss, solid gain and weight loss were studied with variables coded as X_1, X_2, X_3 and X_4 respectively. The ranges of parameter values were carefully chosen based on the literature available on the osmotic dehydration of vegetables prior to drying. The ranges and levels of the parameters are shown in Tab. 1. The levels were determined using the code values of -2, -1, 0, +1, +2 as described by Das (2005).

Table 1. Code and actual values of different variables for experimentation

Variables\Code	*-2*	*-1*	*0*	*+1*	*+2*
Process temperature [°C]	*22*	*31.0*	*40*	*49.0*	*58*
Immersion duration [min]	*30*	*67.5*	*105*	*142.5*	*180*
Salt (NaCl) concentration [%]	*5*	*7.5*	*10*	*12.5*	*15*
Sucrose concentration [%]	*40*	*45.0*	*50*	*55.0*	*60*

The quadratic mode of *CCRD* of 4 variables at 5 levels each with 6 centre point combination was used. Altogether, 54 combinations (including 6 replications at the centre point and 2 replications at other points) were chosen according to design.

Process parameters (Factors i.e., four of five levels).

A. Process temperature (X_1) : 22, 31, 40, 49 and 58°C
B. Immersion duration (X_2) : 30, 67.5, 105, 142.5 and 180 min.
C. Salt concentration (X_3) : 5, 7.5, 10, 12.5 and 15%
D. Sugar concentration (X_4) : 40, 45, 50, 55 and 60%

Total number of treatment combinations (Runs).

$$\begin{aligned}
&\mathit{Total}\ \text{no.of treatments combinations} \\
&= [\text{No. of replications x (2) No. of variables}] \\
&+ [\text{No. of replications x} (2 \times \text{No. of variables}) \\
&+ \text{center points} + \text{control} \\
&= (2 \times 2^4) + (2 \times 2 \times 4) + 6 = 54
\end{aligned}$$

Evaluation of osmotic dehydration characteristics. Osmotic dehydration characteristics of onion slices were evaluated on the basis of solid gain, water loss, weight loss and moisture content.

The solid gain is the net uptake of solids by the onion slices. The water loss is the net loss of water from the product on initial mass basis. The weight loss is the net weight loss of the onion slice on initial weight basis. The solid gain, water loss and mass loss was calculated using the equations suggested by Islam and Flink (1982).

$$SG = \frac{W_\theta(1-X_\theta) - W_i(1-X)}{W_i} \times 100 \tag{2}$$

$$WL = \frac{W_i X_i - W_\theta X_\theta}{W_i} \times 100 \tag{3}$$

$$Weight\ Loss = \frac{W_i - W_\theta}{W_i} \times 100 \tag{4}$$

where:

SG [g·100g^{-1}] - solid gain (g/100g initial mass of slices),
WL [g·100g^{-1}] - water loss (g/100 g initial mass of slices),
W_θ [g] - mass of slices after duration θ,
X_θ [g] - water content as a fraction of mass of slices at duration θ,
W_i [g] - initial mass of slices,
X_i [g] - water content as a fraction of initial mass of slices.

Data analysis and optimization. The *CCD* design was used to conduct experiment and the Response Surface Methodology (*RSM*) was applied to the experimental data using a commercial statistical package, Design Expert-version 8.0.7.1 (Stat-ease, 21012). Analysis of variance (*ANOVA*) was conducted for fitting the model represented by equation 1 to examine the statistical significance of the model terms. Model analysis with respect to lack-of-fit test and R^2 (coefficient of determination) was done for determining adequacy of model. The coefficient of variance (*CV*) was calculated to find the relative dispersion of the experimental points from the prediction of the model. Response surfaces were generated and by using the same software, numerical optimization was done. The most commonly used model for optimization using response surface methodology is a second order polynomial equation [2]. The model is of the form:

$$Y_k = b_{k0} + \sum_{i=1}^{4} b_{ki} X_i + \sum_{i=1}^{4} b_{kii} X_i^2 + \sum_{i \neq j=1}^{4} b_{kij} X_i X_j \quad (k = 0,1,2,3 \ldots) \tag{5}$$

where:

Y_k [-] - response,
b_{k0}, b_{ki}, b_{kii}, b_{kij} [-] - constant, linear, quadratic and corss-product regression coefficients,
X_i’ [-] - coded independent variables.

For optimization purpose the Response Surface Methodology was used.

Numerical optimization technique of the Design-Expert software was used for simultaneous optimization of the multiple responses. The desired goals for each factor and responses were chosen. The goals may apply to either factors or responses. The possible goals are maximize, minimize, target, within range, none (for responses only) and set to an exact value (for factors only). In order to search a solution maximizing multiple responses, the goals were combined into an overall composite function, *D(x)*, called the desirability function [11], which is defined as:

$$D(x) = (Y_1 \times Y_2 \times \ldots \times Y_n)^{1/n} \tag{6}$$

where:

Y_i *(i = 1, 2,….n)* [-] - responses,

n [-] - total number of responses in the measure.

The optimized solution parameters were used for further study i.e., to examine effect of chemical pretreatment on osmotic dehydration of onion slices.

RESULTS AND DISCUSSION

Initial moisture content of onion slices of freshly harvested Talaja Red variety taken for treatments was 86.12%.

Effect of osmotic dehydration parameters on solid gain. The solid gain varied from 3.90 to 17.02%. The minimum solid gain was found in the treatment having the combination of process temperature of 31°C, 67 minutes and 30 seconds immersion duration, 7.50% salt concentration and 45% sugar concentration, while maximum solid gain was found in the treatment having the combination of process temperature of 40°C, 105 minutes and 15 seconds immersion duration, 15% salt concentration and 50% sugar concentration. This showed that salt concentration and sugar concentration played prominent role than the immersion duration and process temperature on solid gain. Similar observation were given by Alam *et al*. (2013), Ispir and Togrul (2009), Jokie *et al*. (2007).

The model *F*-value of 33.36 implies that the model is significant. There is only 0.01% chance that this much large "Model *F*-Value" could occur due to noise. R^2 and *CV*% value for solid gain was 0.9229 and 11.80% respectively which indicated that the model could fit the data for solid gain very well for all the four variables, i.e. process temperature, immersion duration, salt concentration and sugar concentration.

The response surface equation of second order was obtained in terms of coded factors to predict the variation in solid gain during osmotic dehydration of onion slices with varying levels of processing parameters as Eq. 7.

$$\begin{aligned} Solid\ gain(\%) = {} & 6.52 - (7.253E-003)A + 0.055B + 2.29C + 0.59D - 0.16AB + \\ & 0.066AC - 0.82AD - 0.067BC - 0.016BD + 0.37CD - (9.800E- \\ & 003)\,A^2 - 0.018B^2 + 0.72C^2 - (9.256E-003)D^2 \end{aligned} \tag{7}$$

where:

A [°C] - process temperature,

B [min] - immersion duration,

C [%] - salt concentration,

D [%] - sugar concentration.

Effect of process temperature and immersion duration on solid gain. The effect of process temperature and immersion duration on solid gain was determined keeping salt concentration and sugar concentration constant at 10% and 50% respectively (Fig. 1). Three dimensional responses for solid gain of osmotic treated samples were generated. It could be observed that with increase in process temperature and immersion duration, there is increase in solid gain and hence solid gain was directly proportional to process temperature and immersion duration. Solid gain rise was more with increase in process temperature as compared to immersion duration. Interaction effect of process temperature and immersion duration on solid gain was found to be non-significant. Results for apricot also showed that solids gain increased with the increase of temperature [10]. Similar results were also obtained by Souraki *et al*. (2012), Alam *et al*. (2013), Jokie *et al*. (2007), Ramallo *et al*. (2004).

Effect of osmotic dehydration parameters on water loss. The water loss varied from 23.94 to 49.28%. The maximum water loss was found in the treatment combination of process temperature of 40°C, 105 minutes immersion duration, 10% salt concentration, 60% sugar concentration, while minimum water loss was found in treatment combination of process temperature of 31°C, 142 minutes and 30 seconds immersion duration, 12.5% salt concentration, and 45% sugar concentration. This shows that sugar concentration, process temperature and salt concentration played prominent role than the immersion duration on water loss. These observations are in line with those reported by Alam *et al.* (2013).

The model *F*-value of 22.55 implies that the model is significant. There is only 0.01% chance that this much large "Model *F*-value" could occur due to noise. R^2 and *CV*% value for water loss was 0.89 and 6.44% respectively which indicated that the mode could fit the data for water loss very well for all the four variables, i.e., process temperature, immersion duration, salt concentration and sugar concentration.

The response surface equation of second order was obtained in terms of coded factors to predict the variation in water loss during osmotic dehydration of onion slices with varying levels of processing parameters as under:

$$\begin{aligned}&Water\ loss(\%) = 34.70 + 1.29A + 0.45B - 0.66C + 4.97D - 0.46AB - 0.18AC\\&-1.10AD + 0.27BC + (2.160E - 0.003)BD + 0.28CD - 0.90A^2 - 0.67B^2\\&-0.28C^2 + 1.25D^2\end{aligned} \quad (8)$$

Effect of process temperature and immersion duration on water loss. The effects of process temperature and immersion duration on water loss were determined keeping salt concentration and sugar concentration constant at 10% and 50% respectively (Fig. 2). Three dimensional responses revealed that with increase in process temperature and immersion duration, there was increase in water loss and hence water loss was directly proportional to process temperature and immersion duration. Water was considerably more with increase in process temperature as compared to immersion duration. Interaction effect of process temperature and immersion duration was found to be non-significant on water loss.

Effect of osmotic dehydration parameters on weight loss. The weight loss varied from 16.57 to 42.20%. The maximum weight loss was found in treatment combination of process temperature of 40°C, 105 minutes immersion duration, 10% salt concentration and 60% sugar concentration, while minimum weight loss was found in treatment combination of process temperature of 31°C, 142 minutes immersion duration, 12.5% salt concentration and 45% sugar concentration. This showed that sugar concentration, salt concentration and process temperature played prominent role than the immersion duration on weight loss. These findings are in line with Ozen *et al*. (2002).

The model *F*-value of 21.48 implies that the model is significant. There is only 0.01% chance that this much large "Model *F*-value" could occur due to noise. R^2 and *CV*% value for weight loss was 0.89 and 7.99% respectively which indicated that the mode could fit the data for weight loss very well for all the four variables, i.e., process temperature, immersion duration, salt concentration and sugar concentration.

The response surface equation of second order was obtained in terms of coded factors to predict the variation in weight loss during osmotic dehydration of onion slices with varying levels of processing parameters as under:

$$\begin{aligned} Weight\ loss(\%) &= 28.18 + 1.30A + 0.40B - 1.63C + 4.38D - 0.30AB - 0.25AC \\ &- 1.02AD + 0.34BC + 0.16BD - 0.91CD - 0.89A^2 - 0.66B^2 - 1.00C^2 + 1.24D^2 \end{aligned} \quad (9)$$

Effect of process temperature and immersion duration on weight loss. The effects of process temperature and immersion duration on weight loss were determined keeping salt concentration and sugar concentration constant at 10% and 50% respectively (Fig. 3). Three dimensional responses revealed that with increase in process temperature and immersion duration, there was an increase in weight loss and hence mass loss was directly proportional to process temperature and immersion duration. Weight loss was considerably more with increase in process temperature as compared to immersion duration. Interaction effect of process temperature and immersion duration was found to be non-significant on weight loss. Results for apricot also showed that solids gain increased with the increase of temperature [7, 9].

Effect of osmotic dehydration parameters on moisture content. The moisture content varied from 44.16 to 69.50%. The minimum moisture content was found in treatment combination of process temperature of 40 °C, 105 minutes immersion duration, 10% salt concentration and 60% sugar concentration, while maximum moisture content was found in treatment combination of process temperature of 31 °C, 142 minutes and 30 seconds immersion duration, 12.5% salt concentration and 45% sugar concentration. This showed that sugar concentration, salt concentration and process temperature played prominent role than the immersion duration moisture content.

The model F-value of 22.55 implies that the model is significant. There is only 0.01% chance that this much large "Model *F*-value" could occur due to noise. R^2 and CV% value for moisture content was 0.89 and 3.71% respectively which indicated that the mode could fit the data for moisture content very well for all the four variables, i.e., process temperature, immersion duration, salt concentration and sugar concentration.

The response surface equation of second order was obtained in terms of coded factors to predict the variation in moisture content during osmotic dehydration of onion slices with varying levels of processing parameters as under:

$$\begin{aligned} &\textit{Moisture content}\,(\%) = 58.74 + 1.29A + 0.45B - 0.66C - 4.97D + 0.46AB + 0.18AC \\ &+ 1.10AD - 0.27BC - (2.160E - 0.003)BD - 0.28CD + 0.90A^2 + 0.67B^2 \\ &+ 0.28C^2 - 1.25D^2 \end{aligned} \quad (10)$$

Effect of process temperature and immersion duration on moisture content. The effects of process temperature and immersion duration on moisture content were determined keeping salt concentration and sugar concentration constant at 10% and 50% respectively (Fig. 4). It could be observed that with increase in process temperature and immersion duration, there is decrease in moisture content and hence moisture content was inversely proportional to process temperature and immersion duration. Decrease in moisture content was considerably more with increase in process temperature as compared to immersion duration. Interaction effect of process temperature and immersion duration on moisture content was found to be non-significant. It was also found that moisture content 0.6 mm thick slices of pineapple was linearly affected with solute content was independent of temperature up to 600 min of initial dehydration [15].

Optimization of osmotic characteristics during osmotic dehydration of onion slices. Optimization of parameters of osmotic dehydration for maximum water loss and minimum solid gain was done based on analysis of various parameters and statistical data. Numerical optimization found a point that maximizes the desirability function and best combination was selected having the desirability function.

Table 2. Optimized variables and their responses for osmotic dehydration of Talaja Red onion slices

Variable	*Optimized values*	*Responses*	*Predicted values*
Process temperature [°C]	*42.08*	*Water loss [%]*	*40.04*
Immersion duration [min]	*111.13*	*Solid gain [%]*	*5.42*
Salt concentration [%]	*8.03*	*Weight loss [%]*	*34.62*
Sugar concentration [%]	*55.00*	*Moisture content [%]*	*53.39*

From the numerical optimization, 41 solutions were found out of which best combination having desirability of 0.781 was selected. The osmotic dehydration of Talaja Red onion slices should be carried out at 42.08°C temperature and 111.13 minutes immersion duration keeping salt concentration and sugar concentration at 8.03% and 55% respectively. This optimum set of parameters gave the predicted values of osmotic dehydration characteristics i.e. solid gain 5.42%, water loss of 40.04%, weight loss of 34.62% and moisture content of 53.39%. The finding in this study were in line with the results reported by Shamaei *et al*. (2012). The optimum values for different variables and their predicted responses thus obtained are given in Tab. 2.

CONCLUSIONS

It may be concluded that the optimal process temperature and immersion duration for onion slice in 8.03% salt concentration and 55% sugar concentration will be 42.08°C and 111.13 minute respectively for maximum water loss and minimum solid gain during osmotic dehydration.

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UTICAJ TEMPERATURE I VREMENA IZLAGANJA NA OSMOTSKU DEHIDRACIJU REŽNJEVA CRNOG LUKA

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Sažetak: U ovom istraživanju su ispitivani gubitak vode, čvrsti prinos, gubitak mase i sadržaj vlage kod osmotski dehidriranog crnog luka (*Allium cepa L.*). Uticaj temperature i vremena na režnjeve crnog luka tokom osmotske dehidracije je optimiziran korišćenjem metode odgovora površine (*RSM*). Povećanje temperature i vremena izlaganja povećava čvrsti prinos, gubitak vode i gubitak mase, a smanjuje sadržaj vlage. Temperatura nije imala značajan uticaj na čvrsti prinos, a imala je značajan uticaj, na nivou značajnosti od 5%, na gubitak vode, gubitak mase i sadržaj vlage. Optimizirane vrednosti temperature i vremena iznosile su 42.08°C i 111.13 min, redom.

Ključne reči*: temperatura, vreme, osmotska dehidracija, crni luk*

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APPLICATION OF ARTIFICIAL NEURAL NETWORKS FOR SHORT TERM RAINFALL FORECASTING

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Abstract: Accurate rainfall forecasting is very necessary for water resource management. Recently, several modeling approaches have been investigated to perform such forecasting task. In the present study, possibility of forecasting rainfall in Junagadh has been analyzed through feed forward artificial neural network models. The 30 years data has been used for training and testing the *ANN* networks. In formulating the *ANN* based Predictive model, single and double hidden layers network have been constructed. The performance of models have been evaluated using Correlation coefficient, Mean Square Error, Normalized Mean Square Error, Akaike's information criterion, Coefficient of Efficiency and volumetric error, and two best suitable models (7-12-13-1 and 4-6-4-1) have been selected from case I and II for rainfall forecasting in Junagadh. Based on the performance evaluation of the models, two models found suitable for prediction of daily rainfall for the study area.

Key words: artificial neural network, feed forward algorithm, rainfall prediction, back propagation algorithm

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INTRODUCTION

The climate change is expected to affect precipitation and water availability. Gujarat mainland region receives an average annual rainfall of 800 to 2000 mm, while Saurashtra has an average annual rainfall of 400 to 800 mm. The The incidence and distribution of rainfall, particularly in Saurashtra and Kutch regions and in the northern part of Water scarcity and droughts are not new phenomena for the people of Saurashtra. They have always lived with them and thus have treated water as a highly scarce and precious resource. The above facts lead to conclude that the artificial neural network is the most efficient rainfall forecasting methods for bringing the more agricultural productions from the limited land and water resources. Artificial Neural Networks (*ANN*s) are non-linear mapping structures based on the functions of human brain. They are powerful tools for modeling, especially when the underlying data relationship is unknown. The artificial neural network is the most efficient rainfall forecasting methods for bringing the more agricultural productions from the limited land and water resources.

Different scientist over the globe have developed stochastic weather models which are basicallystatistical models that can be used as random number generators whose output resembles the weather data to which they have been fit (Wilks, 1998). Guhathakurta (2006) implemented *ANN* technique to predict rainfall over a state (kerala) of India. Hu (1964) initiated the implementation of *ANN*, an important soft computing methodology in weather prediction. Michaelides *et al.* (1995) compared the performance of *ANN* with multiple linear regressions in estimating missing rainfall data over Cyprus. Singh *et al.* (2012) has developed radial basis neural network (*RBNN*) for Nagwa watershed for simulating monthly surface runoff and sediment yield.. Abbot and Marohasy (2012) used artificial intelligence to monthly and seasonal rainfall forecasting in Queensland, Australia. It was assessed by inputting recognized climate indices, monthly historical rainfall data, and atmospheric temperatures into a prototype stand-alone, dynamic, recurrent, time-delay, artificial neural network. Chauhan and shrivastava (2012)developed *ANN* models for estimation of reference crop evapotranspiration with climate data required for Penman-Monteith (*P-M*) method, to test artificial neural networks (*ANN*s) for estimating reference evapotranspiration (*ET0*) with limited climate data (*ET0*) and compares the performance of *ANN*s with P-M method. Nastos *et al.* (2013) developed predictive models in order to forecast rain intensity (mm/day) in Athens, Greece, using Artificial Neural Networks (*ANN*) models. The objectives of the present study were to formulate Artificial Neural Network model with reliable accuracy and validate formulated models for the study area.

MATERIAL AND METHODS

The Main objective of this study is to developed Artificial Neural Networks models for forecasting of monsoon rainfall. This Chapter deals with the location and climate of study area, collection of meteorological data, methodology adopted for rainfall modeling using artificial neural networks models. Procedure used for calibration and validation of the model and various criteria for evaluating performance of the models discussed here.

Descriptions of area. The study area falls in the District of Junagadh (Gujarat), India. The latitude and longitude of the study area is 21.5° N and 70.1° E, respectively. The elevation of gauging station is 60 m above the mean see level. The climate of area is subtropical and semi-arid type with an average annual rainfall of 900 mm and average annual pan evaporation of 6.41 mm/day. May is the hottest month with mean monthly temperature varying between 35 °C to 45 °C and mean monthly minimum temperature varying between 7 °C and 10 °C as observed from the 10 years data collected by meteorological observatory, Krushigadh, *JAU*, Junagadh.

Data acquisition. The daily meteorological data of 30 years (1979 to 1981, 1984 to 1989 and 1991 to 2011) were collected from meteorological observatory of Krushigadh, Junagadh Agricultural University. The Observatory is situated at Junagadh in the "Saurastra" region of Gujarat state of India.

Development of models for study area. The forecasting of rainfall is very complex and non-linear process, which is affected by many factors which inter-related, some of the parameters includes as vapour pressure, relative humidity, wind velocity, dry and wet bulb temperature and mean temperature etc. Models can identify and learn correlated patterns between input data sets and target values. After training, Models can be used to forecast the outcome of new independent data. In this present study Artificial Neural Networks models have been developed for forecasting rainfall on daily basis.

Artificial neural networks (ANNS). Artificial neural networks (*ANN*s) are inspired by the structure of human brain that is well suited for complicated task such as rainfall prediction, rainfall-runoff modeling, river flow modeling etc., in hydrologic systems. This approach is based on the human brain and it is faster compared with its conventional compatriots, flexible in the range of problems it can solve, and highly adaptive to the newer environments. The process of training is an important aspect, and the performance of an *ANN* is dependent on successful training. The training procedure involves the adjustment of connection between weights and threshold values for each of the nodes. The Fig. 1 shows mathematical representation of *ANN* model.

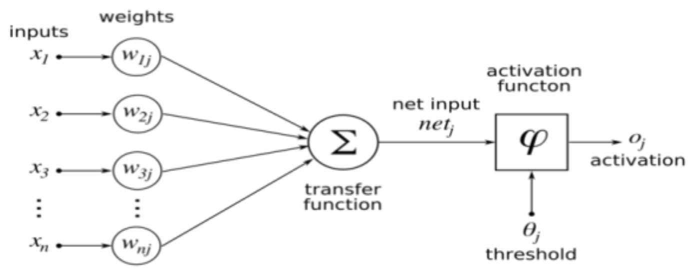

Figure 1. Mathematical representation of neural network

Back-propagation training algorithm. Back-propagation training algorithm is the most commonly used supervised algorithm for training the multi hidden layer *ANN*. In back-propagation *ANN*, information is processed in the forward direction from the input layer to the hidden layer(s) and then to output layer. The objective of a back-propagation network is to find the weights that approximate target values of output with a selected accuracy. It requires a continuous, differentiable and non-linear function on the *ANN* to compute output from each neuron.

The input data are multiplied by the initial weights, then the weights inputs are added by simple summation to yield the net input to each neuron.

$$Net = \sum_{i=1}^{N} V_{ji} X_i \tag{1}$$

where:
X_i [-] - input to any neuron,
V_{ji} [-] - weighted matrix from j^{th} layer to i^{th} layer,
N [-] - number of inputs,
Net [-] - net for j^{th} neuron.

Development of ANN model. In this method, there is a combinations prepared as input of the *ANN* model. The following two cases of the data sets were taken in account for the modeling of *ANN* for rainfall prediction.

Case I: In this case N = 149 days in year and M = 30 years (1979-1981, 1984-1989 and 1991-2011). Let the observed values of vapor pressure, relative humidity, wind velocity, temperature and rainfall represented as $VP_{i,j}$, $RH_{i,j}$, $V_{i,j}$, $T_{i,j}$ and $P_{i,j}$ respectively for j^{th} day of the i^{th} year (i = 1,2,….,M and j = 1,2,…,N).

The functional form of the models can be represented as:

$$P_{i,j} = f(P_{i,j-3}, P_{i,j-2}, P_{i,j-1}, VP_{i,j-1}, RH_{i,j-1}, V_{i,j-1}, T_{i,j-1}) \tag{2}$$

It can be seen from Eq. 2, there are 7 numbers of input and one number of output in this case. Denoting input variables by $X_1, X_2, ..., X_7$ and output by Y, the year wise arrangement of input and output variables is shown in Tab. 3.3. Thus each row of Tab. 3.2 will represent an input-output pair for the development of the artificial neural network model.

Case II: In this case the observed time series of vapour pressure, relative humidity, wind velocity, temperature and rainfall of previous days are taken as the input variables and current day rainfall as the output variable, considering rainfall occurrence period starting from 1st June to 30th October only. In this case N = 152 days in year and M = 30 years (1979-1981, 1984-1989 and 1991-2011). Let the observed values of vapour pressure, relative humidity, wind velocity, temperature and rainfall represented as $VP_{i,j}$, $RH_{i,j}$, $V_{i,j}$, $T_{i,j}$ and $P_{i,j}$ respectively for j^{th} day of the i^{th} year (i = 1,2,….,M and j = 1,2,…,N).

The functional form of the models can be represented as:

$$P_{i,j} = f(VP_{i,j-1}, RH_{i,j-1}, V_{i,j-1}, T_{i,j-1}) \tag{3}$$

It can be seen from Eq. 3.15, there are 4 numbers of input and one number of output in this case. Denoting input variables by $X_1, X_2, ..., X_4$ and output by Y, the year wise arrangement of input and output variables is shown in Tab. 3.3. Thus each row of Tab. 3.2 will represent an input-output pair for the development of the artificial neural network model.

RESULTS AND DISCUSSION

Performance evaluation of model. Qualitative and quantitative evaluation of model is an important task to assess their capability or potential of developed model in simulation of actual circumstances. In the present study the following qualitative and quantitative performance indices were applied to verify the applicability of developed *ANN* model.

Table 1. Performance indicators

Indicator	*Equation*
Mean Square Error (MSE)	$MSE = \frac{\sum_{j=1}^{n}\left(Y_j - Y_{ej}\right)^2}{n}$
Normalized Mean Square Error (NMSE)	$NMSE = \frac{P\ N\ MSE}{\sum_{j=0}^{P} \frac{N\sum_{i=0}^{N} {d_{ij}}^2 - \left(\sum_{i=0}^{N} d_{ij}\right)^2}{N}}$
Correlation Coefficient (CC)	$CC = \frac{\sum_{j=1}^{n}\left\{\left(Y_j - \bar{Y}\right)\left(Y_{ej} - \overline{Y_{ej}}\right)\right\}}{\sum_{j=1}^{n}\left(Y_j - \bar{Y}\right)^2 \sum_{j=1}^{n}\left(Y_{ej} - \overline{Y_{ej}}\right)^2} \times 100$
Akaike's Information Criterion (AIC)	$AIC = 2k + n\ ln\left(\frac{2E}{n}\right)$
Coefficient of Efficiency (CE)	$CE = \left(1 - \frac{\sum_{i=1}^{n}\left(Y_j - Y_{ej}\right)^2}{\sum_{i=1}^{n}\left(Y_j - \bar{Y}\right)^2}\right) \times 100$
Volumetric Error (EV)	$EV = \left[\frac{\sum_{j=1}^{n}\left(Y_{ej} - Y_j\right)}{\sum_{j=1}^{n}\left(Y_j\right)}\right] \times 100$

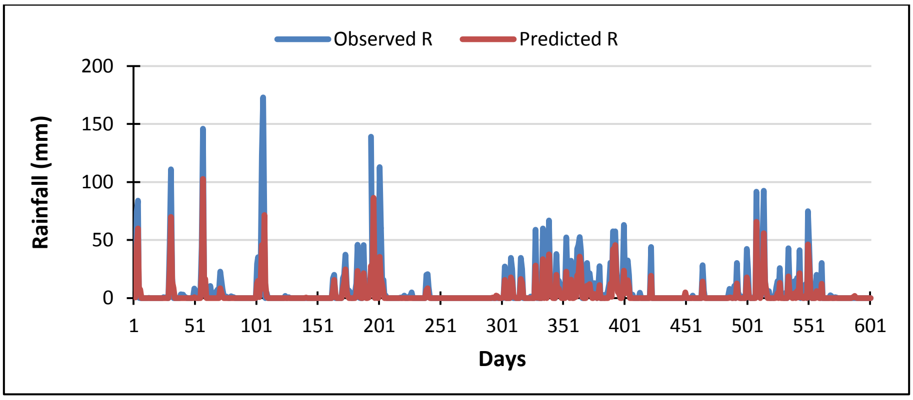

Figure 2. Observed and Predicted daily rainfall using ANN model (7-30-1) during testing period

The performance of the models was evaluated qualitatively and quantitatively by visual observation and employing various statistical indices viz. correlation coefficient, mean square error, normalized mean square error, Akaike's information criterion, co-efficient of efficiency and volumetric error (Tab. 1). The qualitative performance of the single and double hidden layer models (7-30-1), (4-12-1), (7-12-13-1) and (4-6-4-1) are shown in the (Figs. 2, 3, 4 and 5) respectively for the testing periods. In this study, the acceptable limits for the correlation coefficient, mean square error have been considered to be above 75%, and less than 0.01 respectively for quantitative performance of the models. For the comparison of different models, the Mean square error, Correlation coefficient and Akaike's information criterion of different model are calculated (Tab. 2).

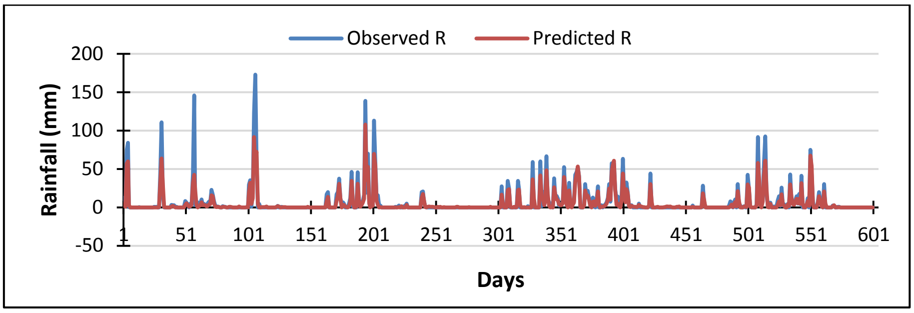

Figure 3. Observed and predicted daily rainfall using ANN model (7-12-13-1) during testing period

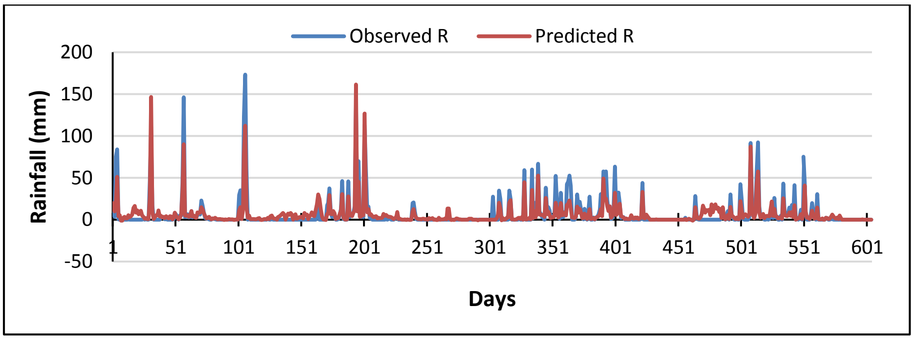

Figure 4. Observed and predicted daily rainfall using ANN model (4-12-1) during testing period

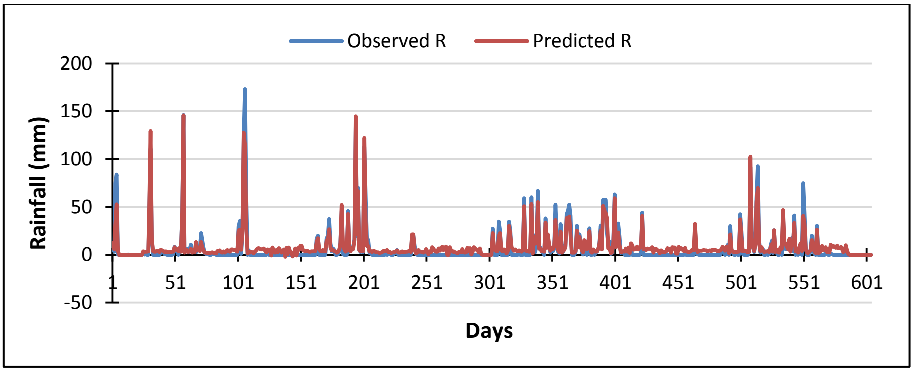

Figure 5. Observed and predicted daily rainfall using ANN model (4-6-4-1) during testing period

Quantitative evaluation. For better appreciation of the model, the predictive effectiveness of *ANN* model is judged on the basis of performance indicators. To judge the predictive capability of the developed model, Correlation Coefficient, Mean Square Error (*MSE*), Normalized Mean Square Error (*NMSE*), Akaike's Information Criterion (*AIC*), Coefficient of Efficiency (*CE*) and Volumetric Error (*EV*) were employed (Tab. 1). The Y_j is observed values, Y_{ej} is the predicted values, $\bar{Y}$ is the mean of observed values, n is the number of observations, P is the number of output processing elements, N is the number of observation in the data sets, *MSE* is mean squared error, d_{ij} is the desired output for observation i at processing element j, E is the sum-square-error, k is the number of parameters.

Table 2. Quantitative performance evaluation of developed models during testing for the best chosen network for ANN

Performance indies	*Single Hidden Layer ANN Network*		*Double Hidden Layer ANN Network*	
	7-30-1	*4-12-1*	*7-12-13-1*	*4-6-4-1*
MSE	*0.0015*	*0.0006*	*0.0008*	*0.0003*
NMSE	*0.43*	*0.37*	*0.40*	*0.29*
CC	*0.80*	*0.89*	*0.89*	*0.95*
AIC	*-3275.82*	*-4250.50*	*-3472.79*	*-4691.61*
CE	*69.7*	*83.48*	*82.5*	*87.1*
EV	*42.14*	*17.34*	*24.7*	*13.54*

Correlation coefficient (CC). The values of correlation coefficient for artificial neural networks models were computed. Based on *ANN* model, the values of correlation coefficient for Junagadh testing of single and double (7-30-1, 4-12-1, 7-12-13-1 and 4-6-4-1) hidden layers networks (2008-2011) of periods are 80.00, 89.00, 89.00 and 95.00 % respectively (Tab. 2). The higher values of correlation coefficient for testing periods show good agreement between observed and predicted values of rainfall. According to the correlation coefficient, the model 4-6-4-1 has better accuracy than the other selected models.

Mean square error (MSE). The mean square error (*MSE*) values between observed and predicted values of rainfall based on developed models of rainfall for single and double hidden layers (7-30-1, 4-12-1, 7-12-13-1 and 4-6-4-1) for testing periods are 0.0015, 0.0006, 0.0008 and 0.0003 respectively (Tab. 2). The lowest *MSE* shows the higher performance of the model and the model 4-6-4-1 has lowest *MSE*.

Normalized mean square error (NMSE). The normalized mean square error (*NMSE*), between observed and predicted values for developed single and double hidden layers models were determined and values so obtained. Based on *ANN*s model, the values of Normalized mean square error of developed models (7-30-1, 4-12-1, 7-12-13-1 and 4-6-4-1) for testing period (2008 to 2011) are 0.43, 0.37, 0.40 and 0.29 respectively (Tab. 2). Among all selected models, the model 4-6-4-1 has the lowest *NMSE*.

Akaike's information criterion. The Akaike's information criterion (*AIC*) is used to measure the tradeoff between training performance and network size. The goal is to minimize this term to produce a network with the best generalization. The values of akaike's information criterion of developed models (7-30-1, 4-12-1, 7-12-13-1 and 4-6-4-1) for testing periods are -3275.82, -4250.50, -3472.79 and -4691.61 respectively (Tab. 2). It can be seen from the performance of the models, the model 4-6-4-1 has greater accuracy as compared to the other models.

Coefficient of efficiency. The coefficient of efficiency of developed single and double hidden layer models for rainfall between the observed and predicted values of rainfall were. Applying the *ANN* model, the values of coefficient of efficiency of models (7-30-1, 4-12-1, 7-12-13-1 and 4-6-4-1) for testing periods are 69.7, 83.48, 82.5 and 87.1 % respectively (Tab. 2). The model 4-6-4-1 has higher value of *CE*. The higher value of *CE* show the good association between observed and predicted rainfall.

Volumetric error. The volumetric error of the model was also assessed by another measure i.e. volumetric error. Using the *ANN* models, the values of volumetric error for single and double hidden layers models (7-30-1, 4-12-1, 7-12-13-1 and 4-6-4-1) for testing period are 32.14, 14.34, 14.70 and 13.54 % respectively (Tab. 2). It is observed that the model 4-6-4-1 has lower *EV* and it shows the higher performance of the model.

CONCLUSIONS

In this work, an attempt has been made to train and validate the artificial neural networks models for monsoon season of Junagadh, Gujarat, India. In order to test these models, the actual rainfall data was collected from Junagadh Agricultural University, Junagadh, Gujarat, India for the period of 2008 to 2011. Two different combinations of the input parameters have been used for predict the rainfall. Four different single and double hidden layers models of artificial neural networks having a less mean square error and high correlation coefficient. The model 4-6-4-1 has lowest *MSE* and higher *CC*. The model 4-6-4-1 has been selected from the four models. It has been proved that *ANN*s provide better accurate forecasting of rainfall. These models based on the individuals parameters like vapour pressure, relative humidity, wind velocity and mean temperature.

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PRIMENA VEŠTAČKIH NEURONSKIH MREŽA ZA KRATKOROČNO PREDVIĐANJE PADAVINA

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Sažetak: Precizna prognoza padavina je neophodna za upravljanje vodenim resursima. Skorije je ispitivano nekoliko pristupa modeliranju postupaka ovakvih prognoza. U ovom istraživanju je analizirana mogućnost predviđanja padavina u Junagadh kroz modele veštačkih neuronskih mreža (*ANN*) direktnih distribucija. Za treniranje i testiranje mreža su korišćeni podaci za period od 30 godina. Pri formulisanju prediktivnog modela, zasnovanog na *ANN*, konstruisane su mreže sa jednostruko i dvostruko skrivenim slojevima. Performanse modela su ocenjivane upotrebom koeficijenta korelacije, srednje kvadratne greške, normalizovane srednje kvadratne greške, kriterijuma Akaike informacije, koeficijenta efikasnosti i zapreminske geške, a dva najprilagođenija modela (7-12-13-1 i 4-6-4-1) su izdvojena iz slučajeva I i II za prognozu kiše u Junagadh. Na osnovu ocene performansi ova dva modela su usvojena za predviđanje dnevnih padavina u ispitivanoj oblasti.

Ključne reči: veštačka neuronska mreža, algoritam direktne distribucije, predviđanje padavina, algoritam učenja sa povratnim širenjem

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EFFECT OF MECHANICALLY DAMAGE PERCENTAGE AND OIL TREATMENT ON STORABILITY OF WHEAT IN METAL BIN

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Abstract: Storability of wheat grain was studies in terms of pest population, percent grain damage by insect, percent weight loss, germination percentage and moisture content of grain for different mechanically damage percentage of wheat grain in bulk as well as various quantity of oil treatment to the wheat grain. Individual effect of mechanically damage grain and castor oil treatment on insect infestation of lesser grain borer, percent grain damage and weight loss was found significant after three month of storage whereas their effect on germination percentage and moisture content was non-significant.

Key words*: wheat storage, metal bin, castor oil, grain damage, germination*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of important leading cereal crop with cultivated area (31.19 m ha) and the production (95.91mt.) achieved by India [2].Wheat occupies a central position in agriculture sector and our national economy, used as staple food. Seed are required to be kept in safe storage since they are harvested in the preceding season and usually used for sowing in the subsequent season often after a time gap of six months or longer. Thus proper storage is required to keep seeds in good condition. Pests are more causative factor of corrosion during storages. Among pests, lesser grain borer can effectively endure proliferate under conditions, where the multiplication of most of the insects is restricted. Lesser grain borer, *Rhyzopertha dominica* (F.) is one of the

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primary pests on different types of stored products, mainly grain. One of the alternatives to overcome this problem is application of natural products derived from aromatic plants with potential repellent and insecticidal effect on lesser grain borer, and no harmful effect on human environment [9]. Conventional control measures have been carried out by using insecticides applied directly on grain, or by gas fumigation. So the special attention should be given to pests in storage environment. Lesser grain borers mainly attack wheat, corn, rice and millet. Both the larvae and adults are primary pests. They bore irregularly shaped holes into whole, undamaged kernels and the larvae, immature stages, may develop inside the grain. Larval and adult feeding in and on grain kernels may leave only dust and thin brown shells. A sweet, musty odor is often associated with infestations of this insect. Karanj oil, neam oil, castor oil, are particularly effective as protectors against lesser grain borer [11].

MATERIAL AND METHODS

Wheat harvested by combine harvester were procured from farmer field and it was cleaned to remove broken grains. Mechanical damage grain were mixed in different percent weight (0, 3, 6, and 9%). These grains were treated with castor oil in three different level (i.e. 5, 10 and 15 $ml \cdot kg^{-1}$). Untreated grains were considered as control. The grains were stored in metal bin at room temperature.

Entomological observations such as pest population and percent grain damage by insect were recorded as under.

Pest population. A number of adult pest was counted from each randomly selected sample from each replication and recorded for pest population per sample.

Percent grain damage. A grain damage by pest was counted from 100 randomly selected grains from each sample and recorded percent grain damage.

Physical parameters such as moisture content, percent weight loss and germination percentage were recorded as under.

Moisture content. The moisture content was determined by an oven method, which is a direct method. The grain was weighed and dried, then weighed again according to standard procedures. The moisture content was calculated using the moisture content equations.

Grain moisture content was expressed as a percentage of moisture based on weight (wet basis).

$$M = \frac{w - d}{w} \times 100 \tag{1}$$

where:

w [kg] - wet weight,
d [kg] - dry weight,
M [%] - moisture content.

A representative sample was obtained to provide a useful moisture content evaluation.

Weight loss. Initial weight of wheat at storage time w_a and weight of wheat after six months d_b was noted and calculated as per following formula:

$$\%\, Weight\ loss = \frac{w_a - d_b}{w_a} \times 100 \tag{2}$$

where:
w_a [kg] - initial weight of wheat,
d_b [kg] - weight of wheat after six months.

Percent of germination. One hundred grain of each stored wheat sample were placed and soaked on blotting paper in the Petri dish. Each treatment was repeated eight times. After a period of 72 hours, number of germinated seeds in each Petri dish was counted. The experiment was conducted under Completely Randomized Design (*CRD*). The initial germination percentage of respective sample was calculated by using the following formula.

$$Germination\ \%age = \frac{No. of\ germinated\ seed}{Total\ no. of\ seed\ soaked\ in\ each\ petridish} \times 100 \tag{3}$$

Same procedure was followed after a period of three months to record the final germination % age for grains of wheat.

RESULTS AND DISCUSSION

The experimental work was carried out for two years during the year 2012-13 and 2013-14. Results of pool mean data are presented.

Pest population. The data regarding pest population after three month of storage are given in Tab. 1.

After three month of storage untreated (0% castor oil treatment) wheat grains were infested heavily hence it was discarded. Therefore, three months storage data were analyzed statistically. The mean results showed that the individual effect of mechanically damage grain and castor oil treatment on insect infestation of lesser grain borer was found significant after three month of storage of wheat. Pest population was found lower 2.70 in 0% mechanically damage grain with 15 $ml \cdot kg^{-1}$ castor oil treatment. The infestation of pest was slightly increased with increase of mechanically damage grain of wheat. The infestation of pest was found decreased with increase of castor oil treatment. The all interaction was found non-significant. The pest population remains low in all mechanically damage grain treated with 15 $ml \cdot kg^{-1}$ castor oil.

The mean results showed (Tab. 2) that insect infestation of lesser grain borer was started after two month of storage of wheat and remains up to eight month of storage. Pest population was increased after three month of storage and it was found maximum in untreated castor oil treatments. Hence, all untreated (control) treatment was disposed after three month of storages. The minimum pest population was found in the treatment of 15 $ml \cdot kg^{-1}$ castor oil for all mechanically damage grain after eight month of storage. The results were in line with Kumawat and Naga (2013) in which they observed no pest population in grain treated with 1.0% Neem oil, 1.0% castor oil, 1.0% mustard oil, and 1.0% Taramira oil up to 90 days of treatment.

Table 1. Pest population (Lesser grain borer, Rhizopertha dominica F.) after three month storage of wheat

Treatment	Average No. of adult/ sample					
	2012-13		2013-14		Pooled mean	
Mechanical damage	Square root $\sqrt{x+0.5}$ Transform value	Retrans form value	Square root $\sqrt{x+0.5}$ Transform value	Retrans form value	Square root $\sqrt{x+0.5}$ Transform value	Retrans form value
D1=0%	1.68	2.32	1.90	3.11	1.79	2.70
D2=3%	1.92	3.19	1.92	3.19	1.92	3.19
D3=6%	2.05	3.70	2.01	3.54	2.03	3.62
D4=9%	2.29	4.74	2.15	4.12	2.22	4.43
S.Em.	0.08		0.06		0.05	
CD at 5%	0.21		0.17		0.14	
Castor oil						
O1=5 ml	1.91	3.15	1.94	3.26	1.93	3.22
O2=10 ml	1.28	1.14	1.60	2.06	1.44	1.57
O3=15 ml	1.05	0.60	1.24	1.04	1.15	0.82
O4=0 ml	3.69	13.12	3.20	9.74	3.45	11.40
S.Em.	0.08		0.06		0.05	
CD at 5%	0.21		0.17		0.14	
DxO						
S.Em.	0.15		0.12		0.10	
CD at 5%	NS		0.35		NS	

Table 2. Pest population build up (Lesser grain borer, Rhizopertha dominica F.) during storage of wheat

Sr. No	Treatments		Average No. adult / Sample after months of storage							
	Mechanically damage percentage (%)	Oil treatment (ml·kg^{-1})	1	2	3	4	5	6	7	8
1	0	5	0	0	0.50	2.75	3.75	1.50	-	-
2		10	0	0	0.25	1.00	1.25	0.50	1.50	1.75
3		15	0	0	0	0	0.25	-	0.25	0.75
4		0	0	5.00	8.00	-	-	-	-	-
5	3	5	0	0	1.50	4.75	-	2.00	-	-
6		10	0	0	0.50	1.75	1.75	0.50	2.25	2.75
7		15	0	0	0	0.25	0.75	-	0.75	0.75
8		0	0	8.25	11.25	-	-	-	-	-
9	6	5	0	0.25	2.75	4.75	-	3.25	-	-
10		10	0	0	0.25	2.25	2.75	1.50	2.00	
11		15	0	0	0	0.50	0.75	-	1.00	1.00
12		0	0	8.75	10.75	-	-	-	-	-
13	9	5	0	0.25	3.25	5.75	-	3.25	-	-
14		10	0	0.50	1.00	2.00	2.75	1.75	3.00	
15		15	0	0	0	0.25	2.00	-	1.50	1.50
16		0	0	10.75	12.75	-	-		-	-

The powders and oils of *A. indica*, *A. occidentale* and *M. oleifera* seeds tested were toxic to the rice weevil, *S. oryzae* [10]. *A. indica* has been found to be effective against the maize weevil, *S. zeamais* and cowpea bruchid, *C. maculatus* [6]. This has been attributed to the presence of triterpenoids, which include azadirachtin, salanin and meliantriol in *A. indica* [6, 15]. The oil also blocked the spiracles which might have led to suffocation of the insects [1,7]. Most insects breathe through the trachea which usually leads to the opening of the spiracle. These spiracles might have been blocked by the powders and extracts thereby leading to suffocation [6,15].

Percent of grain damage. The data regarding percent grain damage after three month of storage are given in Tab. 3.

Table 3. Percent of grain damage by lesser grain borer after three month storage of wheat

Treatment	*Percent of grain damage by lesser grain borer*					
	2012-13		*2013-14*		*Pooled mean*	
Mechanical damage	*Arcsin √x transform value*	*Retrans form value*	*Arcsin √x transform value*	*Retrans form value*	*Arcsin √x transform value*	*Retrans form value*
D1=0%	*9.57*	*2.76*	*13.70*	*5.61*	*11.64*	*4.07*
D2=3%	*12.65*	*4.80*	*14.78*	*6.51*	*13.72*	*5.63*
D3=6%	*13.24*	*5.25*	*15.94*	*7.54*	*14.59*	*6.35*
D4=9%	*15.38*	*7.03*	*18.58*	*10.15*	*16.98*	*8.53*
S.Em.	*0.54*		*0.41*		*0.34*	
CD at 5%	*1.54*		*1.17*		*0.95*	
Castor oil						
O1=5 ml	*9.10*	*2.50*	*15.86*	*7.47*	*12.48*	*4.67*
O2=10 ml	*4.14*	*0.52*	*14.08*	*5.92*	*9.11*	*2.51*
O3=15 ml	*2.65*	*0.21*	*8.98*	*2.44*	*5.82*	*1.03*
O4=0 ml	*34.95*	*32.82*	*24.08*	*16.65*	*29.51*	*24.26*
S.Em.	*0.54*		*0.41*		*0.34*	
CD at 5%	*1.54*		*1.17*		*0.95*	
DxO						
S.Em.	*1.08*		*0.82*		*0.68*	
CD at 5%	*3.07*		*2.34*		*1.91*	

The mean results showed in Tab. 3 indicated that the individual effect of mechanically damage grain, castor oil treatment and storage bag/bin on damage of grain due to insect was found significant after three month of storage of wheat The percent damage of grain was found lower 4.07 in 0% mechanically damage grain, 15 $ml \cdot kg^{-1}$ castor oil treatment and storage metal bin respectively. The damage was slightly increased with increase of mechanically damage grain of wheat. The damage was found decreased with increase of castor oil. The damage of grain was found minimum in metal bin container treatments. The all interaction were found significant. The pest damage was found low in all mechanically damage grain, all 15 ml castor oil and all metal bin storage treatments as compared to control.

The mean results showed in Tab. 4 that damage of grain due to insect was started after two month of storage of wheat and remains up to eight month of storage. Damage of grain was increase after three month of storage and it was found maximum in untreated castor oil treatments. Hence all untreated (control) treatment disposed after three months of storage. The minimum damage was found in the treatment of of 15 ml·kg^{-1} castor oil for all mechanically damage grain of 15 ml·kg^{-1} castor oil for all mechanically damage grain after eight month of storage. Kumawat and Naga (2013) reported for up to 90 days of treatment, no grain damage was recorded in 1.0% castor oil treated grain, and no grain damage was recorded in 1.0% Tarmira oil treated grain for up to 90 days of treatment.

Table 4. Percent grain damage during storage of wheat due to insect infestation of lesser grain borer

Sr. No	*Treatments*		*% of grain damage after months of storage*							
	Mechanically damage percentage (%)	*Oil treatment (ml·kg^{-1})*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	*0*	*5*	*0*	*0*	*0.75*	*4.75*	*8.50*	*-*	*-*	*-*
2		*10*	*0*	*0*	*0.75*	*1.50*	*2.75*	*2.25*	*3.00*	*3.50*
3		*15*	*0*	*0*	*0*	*0*	*0.50*	*1.00*	*1.50*	*1.75*
4		*0*	*0*	*6.25*	*17.00*	*-*	*-*	*-*	*-*	*-*
5	*3*	*5*	*0*	*0*	*3.50*	*10.50*	*-*	*-*	*-*	*-*
6		*10*	*0*	*0*	*1.00*	*2.50*	*3.00*	*3.50*	*4.25*	*5.00*
7		*15*	*0*	*0*	*0*	*0.25*	*1.00*	*1.25*	*1.50*	*2.00*
8		*0*	*0*	*8.25*	*24.50*	*-*	*-*	*-*	*-*	*-*
9	*6*	*5*	*0*	*0*	*3.00*	*10.50*	*-*	*-*	*-*	*-*
10		*10*	*0*	*0*	*1.50*	*3.25*	*4.00*	*4.25*	*5.00*	
11		*15*	*0*	*0*	*0*	*0.50*	*1.50*	*2.00*	*2.25*	*2.50*
12		*0*	*0*	*10.5*	*24.50*	*-*	*-*	*-*	*-*	*-*
13	*9*	*5*	*0*	*1.00*	*4.25*	*15.00*	*-*	*-*	*-*	*-*
14		*10*	*0*	*0.25*	*0.75*	*3.75*	*4.75*	*6.25*	*7.00*	*-*
15		*15*	*0*	*0*	*0*	*1.00*	*2.25*	*2.75*	*3.00*	*3.25*
16		*0*	*0*	*12.50*	*30.25*	*-*	*-*	*-*	*-*	*-*

Weight loss. The data regarding weight loss after three month of storage are given in Tab. 5.

The mean results showed in Tab. 5 indicated that the individual effect of mechanically damage grain and castor oil treatment on weight loss was found significant after three month of storage of wheat. The percent weight loss was found lower 1.23 and 0.80 in 0% mechanically damage grain and 15 ml castor oil treatment respectively. The weight loss was slightly increased with increase of mechanically damage grain of wheat. The weight loss was found decreased with increase of castor oil. The all interaction were found non-significant.

However, looking to the mean data in Table No. 6 indicated that in all mechanically damage grain, weight loss was found low in all 15 ml castor oil treatments as compared to control after three and six month of storage. The weight loss was recorded high in the all control (untreated) treatments which may be due to high insect grain damage. Weight loss was found low in *D1O2, D1O3, D2O3, D3O3* and *D4O3* after six month of storage. The findings are in line with Arya and Tiwari (2013). They reported that indigenous plant and animal origin bio products have been found significantly effective over untreated control as more insect mortality, less adult emergence, seed damage, weight loss with more percent seed germination.

Table 5. Percent of weight loss after three month storage of wheat

Treatment	2012-13		2013-14		Pooled mean	
Mechanical damage	Arcsin √x transform value	Retrans form value	Arcsin √x transform value	Retrans form value	Arcsin √x transform value	Retrans form value
D1=0%	6.05	1.11	6.68	1.35	6.36	1.23
D2=3%	6.41	1.25	7.30	1.61	6.85	1.42
D3=6%	6.58	1.31	7.47	1.69	7.03	1.50
D4=9%	6.95	1.46	7.91	1.89	7.43	1.67
S.Em.	0.23		0.18		0.15	
CD at 5%	NS		0.52		0.42	
Castor oil						
O1=5 ml	5.42	0.89	7.27	1.60	6.34	1.22
O2=10 ml	4.63	0.65	6.59	1.32	5.61	0.96
O3=15 ml	4.49	0.61	5.74	1.00	5.12	0.80
O4=0 ml	11.45	3.94	9.76	2.87	10.61	3.39
S.Em.	0.23		0.18		0.15	
CD at 5%	0.67		0.52		0.42	
DxO						
S.Em.	0.47		0.36		0.30	
CD at 5%	NS		NS		NS	
CV%	17.68		12.18		14.88	

Table 6. Percent weight loss after three month and six month of storage of wheat

Sr. No.	Treatment		After 3 months			After 6 months		
	Mechanically damage percentage	Oil treatment ($ml \cdot kg^{-1}$)	2012 - 2013	2013 - 2014	Average	2012 - 2013	2013 - 2014	Average
1	0	5	0.65	1.20	0.925			
2		10	0.50	0.75	0.625	0.70	1.00	0.85
3		15	0.40	0.40	0.40	0.60	0.80	0.70
4		0	3.50	2.65	3.075	-	--	
5	3	5	0.90	1.35	1.125	-	-	
6		10	0.50	1.10	0.8	1.20	1.20	1.20
7		15	0.55	0.50	0.525	0.85	0.85	0.85
8		0	4.00	2.80	3.4	-	-	
9	6	5	0.80	1.50	1.15	-	-	
10		10	0.60	1.35	0.975	1.10	1.50	1.30
11		15	0.65	0.60	0.625	0.88	0.90	0.89
12		0	2.95	2.90	2.925	-	-	
13	9	5	0.90	1.75	1.325	-	-	
14		10	0.70	1.25	0.975	1.70	1.60	1.65
15		15	0.60	0.70	0.65	1.00	1.05	1.025
16		0	4.10	3.20	3.65	-	-	-

Table 7. Percent of germination and percent of moisture content after six month of storage of wheat

Sr. No.	Treatment	% Germination after six month			% M. C. after six month		
		2012-13	2013-14	Average	2012-13	2013-14	Average
1	D1O2	92.5	68.0	80.25	7.74	9.94	8.84
2	D1O3	95.0	76.0	85.50	6.95	9.34	8.14
3	D2O2	90.0	66.0	78.00	7.06	10.37	8.71
4	D2O3	92.5	74.0	83.25	7.86	9.38	8.62
5	D3O2	90.0	64.0	77.00	7.55	10.48	9.01
6	D3O3	92.5	72.0	82.55	7.98	9.72	8.85
7	D4O2	85.0	62.0	73.50	7.92	10.68	9.30
8	D4O3	90.0	68.0	79.00	8.02	9.81	8.91

The mean data in Tab. 7 indicated that the percent germination was found 73.5% to 85.5% after six month of storage in remaining treatment. The germination was recorded higher in any mechanically damage grain with 15 ml castor oil treatment after six month of storage this may be due to low pest damage of grain. From the above mentioned results it can be concluded that mite are responsible for the reduction in germination of wheat grains. Bashir *et al.*, (2009) also revealed that with the increase in mite population the germination of the seeds reduces. Based on these results it can be concluded that pests are mainly responsible for the germination loss in the stored grains [12]. The present findings are almost in agreement with those of Mamun and shajahan (2011) where they reported that with plant materials and extracts did not adversely affect the seed germination.

The mean data in Tab. 7 indicated that the percent moisture content of grain in remaining treatment was found 8.14% to 9.30% after six month of storage and it was found minimum(8.14%) in treatment 0% mechanical damage and 15 ml oil treatment and maximum (9.30%) in treatment 9% mechanical damage and 10 ml oil treatment respectively. Moisture content on grain was found slightly low in all 15 ml castor oil treatment as compared to 10 ml castor oil. Moisture content on grain was found low in year 2012-13 due to lack of rain during season. No adverse effect of plant oils was observed on seed viability for up to 270 days of treatments [11].

CONCLUSIONS

It may be concluded that the even after higher percentage of mechanically damage grain, castor oil treatment reduces the pest population, percent grain damage by pest, and weight loss. It has no adverse effect on germination.

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UTICAJ PROCENTA MEHANIČKIH OŠTEĆENJA I TRETMANA ULJEM NA SKLADIŠTENJE PŠENICE U METALNOM SILOSU

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Sažetak: Skladištenje zrna pšenice ispitivano je u zavisnosti od populacije štetočina, procenta oštećenja zrna od insekata, procenta gubitka mase, procenta klijavosti i sadržaja vlage zrna za za različite procente mehaničkih oštećenja zrna pšenice u skladištu. Ispitivane su i različite količine ulja za tretiranje zrna pšenice. Pojedinačni uticaj mehanički oštećenog zrna i tretman ricinusovim uljem na populaciju insekata, procenat oštećenja zrna i gubitak mase bili su značajni posle tri meseca skladištenja, dok njihov uticaj na procenat klijavosti i sadržaj vlage nije bio značajan.

Ključne reči*: skladištenje pšenice, metalni silos, ricinusovo ulje, oštećenje zrna, klijanje*

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USING HYDRUS-2D MODEL FOR SIMULATING SOIL WATER DYNAMICS IN DRIP-IRRIGATED CITRUS

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Abstract: The demand of water for irrigation is gradually increasing due to escalating competition for fresh water by urban, industrial, and agricultural users. To sustain or increase agricultural productivity, there is a need to adopt highly efficient irrigation technologies such as drip irrigation in crop production. Studies related to water dynamics in crop root zone is the pre-requisite for efficient and economic design of any irrigation system. In the present study, the water dynamics under drip irrigation was evaluated taking citrus as a test crop in sandy loam soil. The soil water content observed in effective root zone (0–60 cm) of the crop showed that water availability was higher in top 15 cm soil, whereas at 45–60 cm soil depth the water content remained unchanged. Drip emitter placement in tree basin had a good influence on water distribution in root zone. The soil water content was simulated using *HYDRUS-2D* model to compare the observed data of water distribution in the soil in root zone of the crop. The calibrated model predicted all the parameters close to observed values with root mean square (*RMSE*) values ranging from 0.013 to 0.015. However, lower *RMSE* values were observed at deeper soil layers. At fruit maturity stage, water present at 45-60 cm soil depth was predicted to be 12.5% higher in comparison to measured values. Overall, *HYDRUS-2D* model has proved it's ability to predict soil water dynamics with higher accuracy in the present crop and soil condition.

Key words*: citrus, soil water dynamics, drip irrigation, Hydrus-2D*

INTRODUCTION

Water availability is one of the major constraints in crop production. The advent of drip-irrigation is a significant technological improvement in irrigation system, which

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helps to combat water scarcity in agriculture [7,10]. In recent years, the adoption of drip irrigation gains momentum owing to its positive impact on productivity and quality of produces in many crops with less water use with higher energy use efficiency [4,14].

Citrus, a high water requiring evergreen perennial fruit crop, is grown in tropical and sub-tropical regions of world. The sub-optimum soil water in root-zone of the citrus plant during any stage of its growth drastically reduces the fruit yield [9,11]. Irrigation is practiced in all most all the citrus groves of the world to avoid water stress in cropping season. Efficient use of irrigation water is a prerequisite for successful cultivation of citrus in water scarce areas [12].

Basin is the most common method of irrigation used in perennial fruit crops including citrus, although the use of drip irrigation has increased in recent years [5,8]. The role of drip irrigation, mulching, deficit irrigation and rainwater use in improving plant growth, and fruit yield along with water economy is well recognized in different citrus cultivars grown in various regions of the world [6,7,13,18,19]. Irrigation scheduling is vital for improving the efficiency of drip irrigation system, as excessive or sub-optimum water supply to plants has detrimental effects on yield and fruit quality of citrus [10,13]. Moreover, the irrigation water loss due to deep percolation and/ or poor distribution of water in crop root zone causes low water use efficiency under excess and faulty irrigation practices under drip system. To obtain best possible delivery of water under drip irrigation system, decision for optimum distance between emitters and the distance of emitter from tree trunk play an important role [9]. It depends upon the dimensions of the wetted volume and the distribution of water within wetted volume. It is not possible to field studies to take decision on drip layout design in each soil and crop conditions. One of the alternatives to design layout of drip system is through simulation modeling of soil water dynamics in crop root zone.

Several empirical, analytical, and numerical models have been developed and used to simulate soil water content and wetting front dimensions for drip irrigation systems [1,2]. Due to advances in computer speed, and the public availability of numerical models simulating water flow and solute transport in soils, many researchers have used such models for evaluating water flow in soils with drip irrigation systems.

HYDRUS-2D [16] is a well-known Windows based computer software package used for simulating water, heat, and/or solute movement in two-dimensional, variably saturated porous media. This model’s ability to simulate water movement for drip irrigation conditions has been assessed by many researchers [17]. However, the use of the model in tree crop especially citrus has not been found in literature. Keeping this in view, the studies related to soil water dynamics in root zone and its simulation using *HYDRUS-2D* model was undertaken in drip-irrigated citrus. Such an understanding can help in identifying the best irrigation strategy for efficient use of water.

MATERIAL AND METHODS

The present study was conducted with bearing ‘Kinnow’ mandarin (C*itrus reticulata* Blanco) plants budded on Jatti Khatti (*Citrus jambhiri* Lush) rootstock at Indian Agricultural Research Institute (*IARI*), New Delhi. The plant to plant spacing was 4 m, whereas row to row spacing was 5 m. The soil of the experimental site varied from sandy loam (top 40 cm soil) to sandy clay loam (40–100 cm) with bulk density of 1.47-

1.61 g cm^{-3}. The irrigation water was free from salinity (EC, 1.15 dS m^{-1}), alkalinity (*pH*, 7.3) and sodicity (*SAR*, 4.4). The ground water contribution to plant water requirement is assumed to be negligible as water level in the nearby wells of the experimental plot was 15–18 m deep from ground surface.

The experimental site is having semi-arid, sub-tropical climate with hot and dry summers. The hottest months of the year are May and June with mean daily temperature of 39°C, whereas January is the coldest month with mean temperature of 14°C. The mean annual rainfall of the site is 770 mm, out of which around 85% is concentrated mainly during June-September. Irrigation was applied at 100% of the crop evapo-transpiration (*ETc*).

The irrigation was continued from mid-January to June and mid-October to December in each year of experiment. Thirty two 'Kinnow' plants were selected for this experiment and 2 treatments except *FI* were imposed following randomized complete block design, with four replicates per treatment and two plants per replication.

Irrigation water was applied in each alternate day using 6 on-line 8 l h^{-1} pressure compensated drip emitters per tree fixed on two 12 mm diameter lateral pipes (3 emitters per lateral). The emitters were arranged at 1.0 m away from plant stem. The water quantity applied under *FI* was calculated based on 100% class-A pan evaporation rate for Kinnow mandarin in Delhi condition, using the following formula:

$$ETc = K_p \times K_c \times E_p \tag{1}$$

where:

Etc [mm·day^{-1}] - crop evapo-transpiration,
Kp [-] - pan coefficient (0.8),
Kc [-] - crop coefficient (0.85 for mature Kinnow plant),
Ep [mm] - the 2-days cumulative pan evaporation.

The volume of water applied under FI was computed following the formula:

$$V_{id} = \pi\,(D^2 / 4) \times (ET_c - R_e) / E_i \tag{2}$$

where:

V_{id} [lit·$plant^{-1}$] - irrigation volume applied in each irrigation,
D [m] - mean plant canopy diameter measured in N-S and E-W directions,
ETc [mm] - crop evapo-transpiration,
R_e [mm] - effective rainfall depth,
E_i [%] - irrigation efficiency of drip system (90%).

The required amount of water to each irrigation treatment was regulated by adjusting the operating hours based on the actual discharge of the emitters from time to time. The flow of irrigation water in lateral pipes was controlled by lateral valves provided at the inlet end of lateral pipes. The recommended NPK-based fertilizers (354 g N, 160 g P_2O_5 and 345 g K_2O per tree) were applied through drip irrigation system in monthly interval from January to June. Intercultural operation and the plant protection measures against insect pests and diseases were adopted uniformly for all trees in the experimental block, following the recommendations given for Kinnow mandarin in Delhi region

HYDRUS-2D is a finite element model, which solves the Richard's equation for variably saturated water flow and convection-dispersion type equations for heat transport. The flow equation includes a sink term to account for water uptake by plant roots. The model uses convective-dispersive equation in the liquid phase and diffusion equation in the gaseous phase to solve the solute transport problems. It can also handle nonlinear non-equilibrium reactions between the solid and liquid phases, linear equilibrium reactions between the liquid and gaseous phases, zero-order production, and two first-order degradation reactions: one which is independent of other solutes, and one which provides the coupling between solutes involved in sequential first-order decay reactions. The program may be used to simulate water and solute movement in unsaturated, partially saturated and fully saturated porous media. The model can deal with prescribed head and flux boundaries, controlled by atmospheric conditions, as well as free drainage boundary conditions. The governing flow and transport equations are solved numerically using Galerkin-type linear finite element schemes. The current version 2.0 of *HYDRUS-2D* also includes a Marquardt-Levenberg parameter optimization algorithm for inverse estimation of soil hydraulic and/or solute transport and reaction parameters from measured transient or steady state flow and/or transport data.

The root uptake model [3] assigns plant water uptake at each point in the root zone according to soil moisture potential. The total volume of the root distribution is responsible for 100% of the soil water extraction by the plant, as regulated by its transpiration demand. The maximum root water uptake distribution reflects the distribution in the root zone having roots that are actively involved in water uptake. The root zone having maximum root density was assigned the value of 1. Root distribution was assumed to be constant throughout the growing season. Maximum depth for simulation was taken as 60 cm.

Table 1. Predicted soil hydraulic parameters

Soil layer	*Soil depth (cm)*	Q_r (θ_r)	Q_s (θ_s)	*Alpha* (α) (cm^{-1})	η	K_s ($cm\ h^{-1}$)	*l*
1	*0-15*	*0.0403*	*0.3740*	*0.0079*	*1.4203*	*1.09*	*0.5*
2	*15-30*	*0.0396*	*0.3748*	*0.0059*	*1.4737*	*0.7*	*0.5*
3	*30-45*	*0.0338*	*0.3607*	*0.0048*	*1.5253*	*1.39*	*0.5*
4	*45-60*	*0.0261*	*0.3682*	*0.0142*	*1.3875*	*1.22*	*0.5*

There are two commonly used models describing soil moisture behaviour, the Brooks–Corey model and the van Genuchten model. The van Genuchten model is most appropriate for soils near saturation [18]. Soils within the root zone under drip irrigation system remains at near saturation throughout the crop season, Therefore van Genuchten analytical model without hysteresis was used to represent the soil hydraulic properties. Sand, silt and clay content of soil were taken as input and by Artificial Neural Network (*ANN*) prediction; the soil hydraulic parameters were obtained and are given in Tab. 1. Where θ_r and θ_s are the residual and saturated water contents, respectively; α is a constant related to the soil sorptive properties; η is a dimensionless parameter related to the shape of water retention curve and Ks represent the saturated hydraulic conductivity.

Simulation was carried out applying irrigation from a line source as in real case for each individual dripper.

Observed soil water in the soil profile was taken as initial water content. For all simulated scenarios, the bottom boundary was defined by a unit vertical hydraulic gradient, simulating free drainage from a relatively deep soil profile. The no-flux boundary was used on the vertical side boundaries of the soil profile because the soil water movement will be symmetrical along these boundaries. The system was divided into four layers depending on the variability of the soil physical properties. To account the dripper discharge during irrigation, a flux type boundary condition with constant volumetric application rate of dripper for irrigation duration was considered. During no irrigation period, flux was kept as zero. Time variable boundary condition was used in *HYDRUS-2D* simulations to manage the flux boundary depending on irrigation water requirement during irrigation and no irrigation period. A sufficient number of nodes are switched in an iterative way until the entire irrigation flux is accounted for, and the radius of wetted area is obtained. In surface placement of drip lateral, top boundary was considered as at atmospheric condition but a small part of the top boundary, around the dripper from where the water is applied to crop, was taken as time variable boundary condition. Under subsurface placement of drip lateral at 15 and 30 cm depth, the top soil surface was considered at atmospheric boundary condition. The atmospheric boundary is usually placed along the top of the soil surface to allow for interactions between the soil and the atmosphere. These interactions include rainfall, evaporation and transpiration (root uptake) given in the time variable boundary conditions. The flux radius and subsequently fluxes per unit area, resulting from one meter of drip lateral was determined. No-flux boundary is impermeable and does not allow water into or out of the soil profile through it.

To quantitatively compare the results of the simulations, observed and simulated values for water content were compared. The coefficient of efficiency (C_{eff}) and the root mean square error (*RMSE*) were the two statistical indices used to quantitatively evaluate the predictions of the model.

RESULTS AND DISCUSSION

Calibration of model. Soil water distribution in the root zone under drip system can be influenced by soil type, dripper discharge, depth of placement of drip lateral, and stage of the crop grown. The *HYDRUS-2D* model was calibrated mainly for hydraulic conductivity values of the sandy loam soil. Model worked well with the measured hydraulic conductivity values. Results of the calibration for water distribution are presented in Fig. 1 using the output files obtained from model. Graphical displays available in the post processing files of model give spatial and temporal distribution of water content in simulated layers. Model gives spatial and temporal distribution of water content in simulated layers at pre-decided time steps. Field observations for water content in the soil were taken at 4 and 24 h after irrigation. Simulated and observed values of water at 4 and 24 h after irrigation were used to evaluate the performance of the model. Root mean square error (*RMSE*) between simulated and observed values was also estimated to examine the predictability of model. *RMSE* values varied from 0.013 to

0.015. This indicates that Hydrus-2D can be used to simulate the water distribution with very good accuracy.

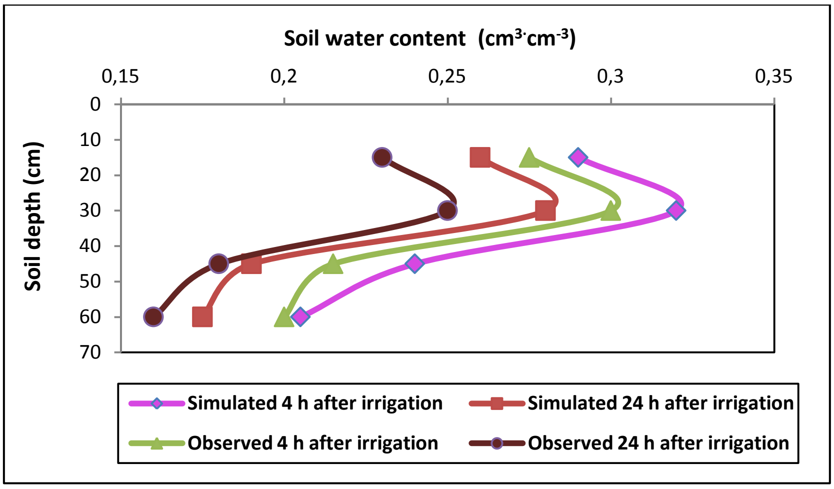

Figure 1. Simulated and observed soil water content at different interval of time with drip irrigation in citrus

Soil water distribution. Soil water content was determined using *FDR* by placing three access tubes at a distance of 0.15, and 30 cm away from lateral pipe up to a depth of 0.6 m. Observed soil water distribution at initial, development, middle and maturity stages are presented in Fig. 2. During the initial growth stage after 30 days of flowering, 23% water content was observed within 5 cm of radius. The downward movement of water was more than its lateral movement at all growth stages of crop due to gravity force playing a predominant role in comparison to the capillary force in experimental plot. The higher value of water content near the drip lateral was also observed in past studies [20]. Soil water content just below the dripper i.e. 0.0 cm away from lateral pipe was more throughout the crop season, almost at the level of field capacity, in all depths of placement of laterals. Soil water content at the surface at initial, developmental, middle and maturity stages of citrus were found to be 23.5, 24.1, 25.0, and 26.1%, respectively

Wetted soil bulb of 30 cm in width and 50 cm depth had more than 17% soil water content, which was very conducive for good growth of crop during initial fruit development stage resulting in higher citrus yields under full irrigation under drip irrigation. Placement of drip lateral at 60 cm distance caused higher soil water content at lower soil depth of 45 and 60 cm in all growth stages of the crop (Fig. 2). At initial and developmental stage of crop, root was confined in top 30 cm soil depth. However, water that moved beyond 60 cm soil depth was less available for plants at any stage.

Higher yield was achieved by maintaining relatively high water content in root zone conducive to good plant growth by placement of lateral at 30 cm distance under successive irrigation event. The high water content of the soil around the drippers facilitates better water transmission to the surrounding soil and keeps on replenishing the crop root zone [15]. Therefore, keeping the drip lateral within the crop root zone and sufficiently distance replenishes the root zone effectively due to gravity flow in light soils and simultaneously reduces evaporation losses due to restricted upward capillary flow.

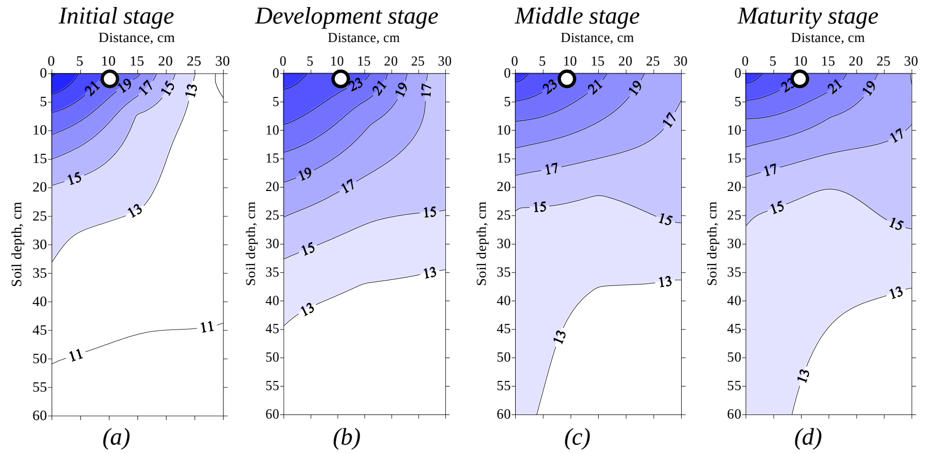

Figure 2. Observed soil water (%, volume basis) distribution in different growth stages of citrus with drip irrigation

Simulation of soil water distribution. The soil water content graphs from the simulated values are presented in Fig. 3 and after comparison from observed values statistical parameters are presented in Tab. 2.

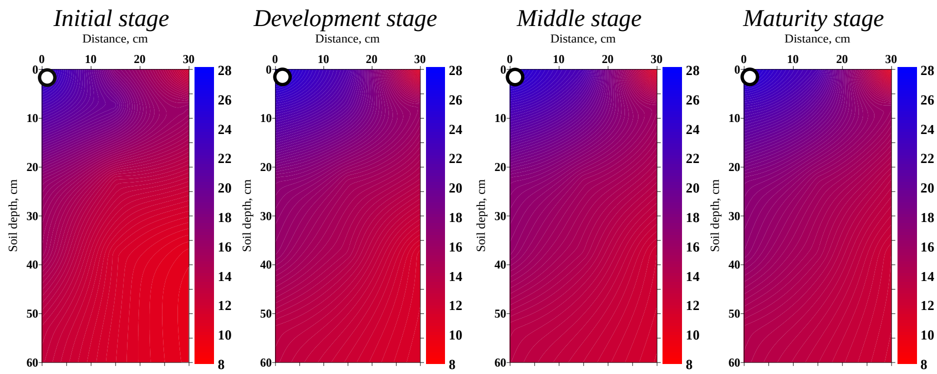

Figure 3. Simulated soil water (%, volume basis) distribution in different growth stages of citrus with drip irrigation

Table 2. Statistical parameters indicative of performance of model for soil water content

Depth of placement of lateral	*Statistical parameters*	*Crop growth stages*			
		Initial	*Developmental*	*Middle*	*Maturity*
Surface (0 cm)	*RMSE*	*0.05*	*0.87*	*0.68*	*0.92*
	$C_{eff.}$	*-0.41*	*-0.01*	*-1.29*	*-2.25*

It shows good agreement between predicted and measured soil water content. The simulated values of water content at soil surface under surface placement of drip lateral were 24.2, 25.1, 25.8, and 25.9% at initial, developmental, middle and maturity stage of the crop. Simulated soil water content above the dripper on soil surface at initial, developmental, middle and maturity stage of the citrus were found 20.3, 18.6, 18.5, and 18.2%, respectively under subsurface placement of drip lateral at 15 cm depth and 7.2, 7.4, 8.5, and 9.8%, respectively under surface placement of drip lateral at 30 cm distance (Fig. 3). The lower *RMSE* values were observed by placement of drip lateral at higher distances with mixed response of coefficient of efficiency.

The input parameters for simulation of *HYDRUS-2D* model were determined by detailed field experimentation, however a few were taken from published literature matching to our soil and similar crop condition. It was found that the wetting patterns obtained during application of water generally consist of two zones, a saturated zone close to the dripper (5 cm around the dripper). The wetting pattern of elliptical shape was found under subsurface placement of drip lateral at 15 cm and 30 cm. Wetted depth was found larger than the surface wetting radius resulting in more water below dripper because of dominant nature of gravity force in comparison to capillary forces. The Saturated radius was taken constant throughout the crop season, from where flux entered. Difference observed between experimental and simulated soil water distribution may be attributed to the differences in saturated hydraulic conductivity of soil (observed and simulated by the model as an intermediate step). The root water uptake model was taken from literature.

CONCLUSIONS

Proper distribution of water in the root zone of citrus is possible with placement of lateral at 60 cm distance from tree trunk. The requirement of large number of accurate parameters matching with the field condition is important. The higher water distribution in soil with higher soil volume under drip enhanced the crop yield. Overall, the Hydrus-2D predicted the soil water with higher accuracy under drip irrigation in citrus, indicating it’s further use in deciding the water management plans under drip irrigation for citrus crops.

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UPOTREBA MODELA HYDRUS-2D ZA SIMULACIJU DINAMIKE ZEMLJIŠNE VLAGE KOD CITRUSA SA NAVODNJAVANJEM KAP PO KAP

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Sažetak: Potrebe za vodom za navodnjavanje se postepeno povećavaju zbog povećanih potreba za svežom vodom u urbanim, industrijskim i poljoprivrednim područjima. Za održavanje i povećanje poljoprivredne proizvodnje potrebno je prilagođavanje visoko efikasnih tehnologija navodnjavanja kao što je navodnjavanje kap po kap. Proučavanje dinamike zemljišne vlage u zoni korenovog sistema je preduslov za efikasno i ekonomično projektovanje sistema za navodnjavanje. U ovom istraživanju analizirana je dinamika vlage kod navodnjavanja kap po kap plantaže citrusa kao oglednog zasada na peskovito-ilovastom zemljištu. Sadržaj zemljišne vode praćen je u efektivnoj zoni korena (0–60 cm) i uočeno je da je dostupnost vode bila veća u gornjih 15 cm zemljišta, dok je na dubini od 45–60 cm sadržaj vode ostao nepromenjen. Položaj kapalice u osnovi stabla uticao je na raspodelu vode u zoni korena. Sadržaj zemljišne vlage bio je simuliran modelom *HYDRUS-2D* radi poređenja izmerenih podataka raspodele vode u zoni korena biljaka. Kalibrisani model je predvideo sve parametre blizu izmerenih vrednosti, sa srednjim kvadratnim odstupanjem od 0.013 do 0.015. Ipak, manje vrednosti odstupanja su uočene u dubljim zemljišnim slojevima. Pri stanju pune zrelosti voća, procenjeni sadržaj vode prisutne na dubini od 45-60 cm bio je 12.5% veći u poređenju sa izmerenim vrednostima. Ukupno, model *HYDRUS-2D* je pokazao svoju sposobnost da predvidi dinamiku zemljišne vlage sa visokom tačnošću kod ovig zasada i i u ovim zemljišnim uslovima.

Ključne reči*: citrus, dinamika zemljišne vlage, navodnjavanje kap po kap, Hydrus-2D*

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SELECTION OF MATERIAL AND HEAT TREATMENT CYCLE FOR WEAR REDUCTION IN OIL PALM (*Elaeis Guineensis*) HARVESTING KNIVES

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Abstract: Harvesting of oil palm is a tedious and labor intensive work. Non-availability of proper tool increases the severity of the problem. Knives used for harvesting the oil palm are either imported or made by local artisans using locally available scrap material. In the present study, oil palm harvesting knives imported from Malaysia and locally made by manufactures in Kerala, India were tested for chemical composition and hardness. On the basis of the results, medium carbon steel was selected for fabrication of oil palm harvesting knives. To obtain the various combinations of microstructure, mechanical properties and wear resistance; these knives were subjected to quenching and tempering treatment with varying tempering temperature (from 250 to 550°C at an interval of 50°C). Abrasive wear resistance of this steel before and after heat-treatment was studied in laboratory using dry sand abrasion test rig as per ASTM G 65 standard at different rotational speed of rubber wheel ranging from 50 to 200 min^{-1} at an interval of 50 min^{-1}. The study revealed that both the factors i.e. tempering temperature and rotational speed of rubber wheel exerted significant influence on abrasive wear resistance. At 250°C tempering temperature, the hardness and abrasive wear resistance is observed to be maximum under the laboratory evaluation. Similar wear resistance behavior was also observed under field condition when the knives were used to cut frond and bunch of oil palm by human laborers.

Key words*: wear rate, steel, heat-treatment, mechanical properties, oil palm harvesting*

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INTRODUCTION

India is the third largest importer of vegetable oils, after China and European Union. The major demand of palm oil arises from the food and cooking oil industries. It is a tree ha**v**ing single stem and pinnate (feather like) leaves. The harvesting of fruits continues till the plant attains 15-20 m height. Harvesting of fruits from the trees taller than 20 m is very difficult. As this is the stage of obtaining maximum productivity from the oil palm, therefore, there is a burning need for development of harvesting devices for these long trees. At present, farmers mostly rely on hand held harvesting tool which is basically a harvesting knife fitted at the end of a long metallic pole or bamboo as depicted in Fig. 1.

Figure 1. Oil palm harvesting knife and harvesting operation

In crop cutting and soil engaging agricultural operations, components are severely subjected to combined effect of chemical action, impact and fatigue loading, operating conditions [1] as well as abrasive wear [2]. These factors exert some influence on the field efficiency and operational cost of the machine [3]. An excellent combination of mechanical as well as tribological properties is desired to overcome the problems arising out of such operational condition. Steel is a widely used material for such applications mainly because of its attaining a wide range of properties, such as hardness, strength, toughness, wear resistance etc., which is not found in any other family of materials [4]. Different alloying elements [5], heat-treatment processes [6,7] and surface modification technologies such as diffusion processes like carburising, nitriding, boriding, surface coatings [8], hard facing [9-11], hot stamping and hard-facing [12] and shot peening [13] processes have been attempted to alter the properties of steels. All above-mentioned treatments change the micro-structural constituents of the material, which alter the hardness and mechanical properties of the steel to induce wear resistance in agricultural machinery. Heat-treatment processes provide extremely excellent combination of mechanical as well as tribological properties. Among them, quenching and tempering is a commonly used popular method to improve the wear resistance and hardness of agricultural implements [14, 15]. Above review indicates that in agricultural engineering applications most of the work pertaining to material selection and its bulk and surface treatment is carried out on soil engaging components like plough share, rotary plough etc and a few attempted has been made for crop cutting components. All the surface treatment process like hard facing, shot peening improves the surface properties of the components as the effected surface is worn out, the component starts behaving like untreated components and requires treatment again. Keeping this fact in mind, the present study was carried out to select appropriate material for fabrication of oil palm harvesting knife and subjecting them to various heat treatment cycles for inducing abrasive wear resistance for higher service life.

MATERIAL AND METHODS

The study was conducted at *ICAE*- Central Institute of Agricultural Engineering, Bhopal and *ICAR*- Indian Institute of Oil Palm Research (*IIOPR*), Pedavegi, Andhra Pradesh during 2013 – 14. One local and two imported oil palm harvesting blades that were being used in India for oil palm harvesting were provided by ICAR- Indian Institute of Oil Palm Research (*IIOPR*), Pedavegi, Andhra Pradesh. Chemical composition and hardness test of the material of these blades were carried out by using Spectroscope and Rockwell hardness tester. Based on these test results, medium carbon steel having comparable chemical composition was selected for manufacturing oil palm harvesting knives. The manufactured knives were subjected to heat-treatment (oil quenching after austenised at 860°C followed by tempering) at Indo-German Tool Room, Indore, Madhya Pradesh as shown in Fig. 2. Tempering was done at different temperatures ranging from 250°C to 550°C for obtaining different combination of mechanical and tribological properties. Specimens made from above heat treated steel sheet were used for microstructural, mechanical and wear testing. After polishing, the hardness of the specimens was measured using Rockwell hardness tester.

Figure2. Heat treatment of oil palm harvesting knives

Abrasive wear was conducted using *DUCOM* dry sand abrasion test rig to measure the wear rate following *ASTM* standard *G-65*. Before testing, the specimens were cleaned, polished according to the standard metallographic techniques, weighed by the electronic balance and then fitted in the specimen holder of the test rig. The specimens were tested at a load of 75 N with four rotational speeds of rubber wheel i.e. 50 min^{-1} (0.93 $m \cdot sec^{-1}$), 100 min^{-1} (1.86 $m \cdot sec^{-1}$), 150 min^{-1} (2.79 $m \cdot sec^{-1}$) and 200 min^{-1} (3.72 $m \cdot sec^{-1}$). The machine stopped after completion of pre-set 200 revolutions. The specimens were then taken out, cleaned and weighed to measure the weight loss due to abrasion. This process was repeated periodically after an interval of 200 revolutions (corresponding to sliding distance of 144 m) till the required sliding distance of 2.6 km was covered. The experiment was replicated thrice and the average values of these three tests were considered.

During tests, wear rate (*WR*) of the specimens were measured from the weight loss measurement at a regular interval of 144 m of sliding distance by using Eq. (1).

$$WR = (W_i - W_f) / (S) \tag{1}$$

where:

W_i [g] - initial weight of specimen before the test,

W_f [g] - final weight of specimen after the wear test,

S [m] - sliding distance.

Factorial Randomized Complete Block Design (*RCBD*) with two factors was adopted for conducting the experiment. A total of eight heat treatment methods, i.e., seven different tempering temperatures and one control (un-tempered) were selected as main factor in the experiment. Four different rotational speeds were selected as sub-factor and all the treatments were replicated thrice in the experiment. The interaction effects between these factors were also estimated to find out the significance of their influence.

The oil palm harvesting knives were evaluated in oil palm orchard for cutting the bunch of oil palm fruits after removing the frond (leaf petiole) engulfing each bunch. The usual plant to plant and row to row spacing for oil palm is 9 m× 9 m with an average plant population of 144 per hectare. Each heat treated harvesting knife was randomly allocated to human labourers for cutting 100 fronds and bunches from oil palms with three replications. After completion of harvesting operation, the wear of material was measured for each knife by electronic balance and expressed in terms of gram per hectare. The experimental data were analysed using *SAS* 9.3 statistical software of *SAS* Institute Inc., USA to find out the significance of the influence of different heat treatment methods on harvesting knives.

RESULTS AND DISCUSSION

The selected oil palm harvesting knives were tested for their chemical composition and hardness. As evident from their chemical composition, medium carbon steels were preferred for making oil palm harvesting knives as given in Tab. 1. The carbon percentage in harvesting knives varied from 0.26 % to 0.46 % along with other alloying elements like silicon, manganese, phosphorus and sulphur etc. which indicated that plain carbon steel was used in these harvesting knives.

The analysis also revealed that the hardness values of the imported knives were in the range of 27-32 *HRc*. Whereas; it was only 16 *HRc* in case of local knife, which was almost 40-50% less as compared to that of imported knives. Less hardness value of these knives is the indication of improper heat-treatment given to them [16]. Based on the chemical analysis, medium carbon steel containing 0.54% carbon, 0.23% silicon, 0.69% manganese, 0.01% phosphorus and 0.008% sulphur was selected for making knives for oil palm harvesting.

Table 1. Chemical composition and hardness of commercial blades

Type of blade	*Chemical Composition [% wt. basis]*					*Hardness [HRc]*
	C	*Si*	*Mn*	*P*	*S*	
Imported-1	*0.46*	*1.47*	*0.57*	*0.023*	*0.037*	*32*
Imported-2	*0.26*	*0.54*	*0.60*	*0.18*	*0.017*	*27*
Local	*0.30*	*0.83*	*0.53*	*0.03*	*0.042*	*16*

After heat-treatment, the hardness of the selected material was tremendously increased. Due to formation of martensitic structure, the hardness of steel increases up to 48 *HRc* after austenizng and quenching in oil as given in Tab. 2, which was reduced to the range of 43 to 25 *HRc* after tempering at different temperatures.

Table 2. Tempering temperature and hardness of the heat-treated knives

Treatment	*Untreated*	*Quenched and untempered*	*Tempering temperature [°C]*						
			550	*500*	*450*	*400*	*350*	*300*	*250*
Hardness [HRc]	*18*	*48*	*25*	*27*	*31*	*34*	*37*	*39*	*43*
Increase in hardness [%]	*-*	*167*	*39*	*50*	*72*	*89*	*106*	*117*	*139*

The effect of sliding distance on abrasive wear rate of control specimen is given in Fig. 3. It was observed that the wear rate reduced initially at a faster rate with increase in the sliding distance during abrasion test irrespective of speed **(**0.93, 1.86, 2.79 and 3.72 $m \cdot s^{-1}$) and finally attained a steady state value. Lowering of the wear rate with sliding distance was due to subsurface work-hardening resulting from subsurface plastic deformation during abrasive wear. Continuous plastic deformation caused work-hardening of the material and wear rate was reduced monotonically with sliding distance as per expectation. But other phenomena like surface and subsurface cracking as well as frictional heating at the subsurface resulted into annihilation of this effect after some time. Same trend of wear rate was also observed for heat treated specimens. The effect of tempering temperature on abrasive wear rate is depicted in Fig.4. It was observed that wear rate reduced with decrease in tempering temperature due to higher hardness value of the material at lower tempering temperatures. Once the tempering temperature reduced below 350℃, the wear rate remained unchanged due to less variation in hardness and other mechanical properties.

The analysis of variance of the factorial experiment is presented in Tab. 3. It was observed that both the tempering temperature and the rotational speed has significant influence on wear rate independent to each other as their interacting influence was found to be non-significant on wear rate.

Among different tempering temperatures applied in this experiment, minimum wear rate was observed when the material was treated at a tempering temperature of 250°C. Wear rate was observed to be increasing with increase in tempering temperature and the control specimen exhibited minimum resistance to abrasive wear (Tab. 4). On the other hand, the resistance to abrasive wear was increasing with increase in rotational speed of the wheel due to less contact time between the wheel and the specimen. Minimum abrasive wear was experienced at a rotational speed of 150 and 200 min^{-1}.

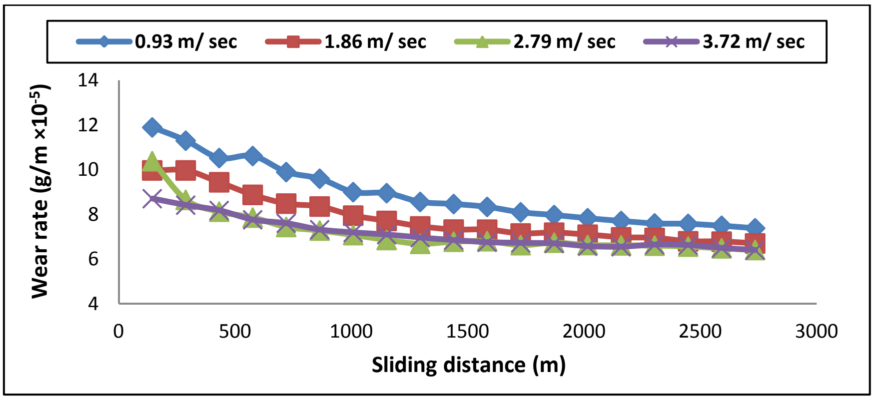

Figure3. Effect of sliding distance on abrasive wear rate of un-treated steel

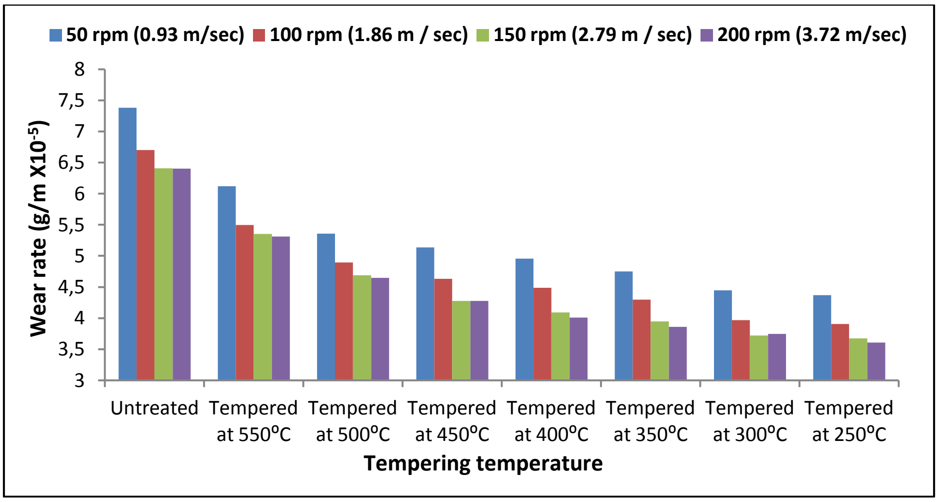

Figure 4. Effect of tempering temperature on abrasive wear rate

The maximum resistance to abrasive wear was obtained when the specimens were subjected to heat treatment applying tempering temperature of 250°C with 200 min^{-1} rotational speed of the wheel (Tab. 5). However, comparable wear resisting behaviour was also observed in the specimens treated at a tempering temperature of 250°C to 350°C with a rotational speed ranging from 150 to 200 min^{-1}. Therefore, the selection of appropriate combination of these two factors is based on their individual influence on wear resistance as the interaction effect was found to be non-significant.

Table 3. Analysis of variance of tempering and speed of operation on wear rate

Source	*Degree of freedom*	*Sum of square*	*Mean sum of square*	*F ratio*
Replication	*2*	*5.4131*	*2.7065*	*17.26****
Tempering temperature [°C]	*7*	*76.5549*	*10.9364*	*69.74****
Speed (min^{-1})	*3*	*10.6770*	*3.5590*	*22.69****
Tempering temperature × min^{-1}	*21*	*0.2689*	*0.0128*	*0.08 ns*
Error	*62*	*9.7234*	*0.1568*	---
Corrected total	*95*	*102.6374*	---	---

**** - Significant at 1% level, ^{ns} – not significant*

Table 4. Wear rate at various tempering temperature and rotational speed

Particular of factor	*Average wear rate [$g \cdot m^{-1} \times 10^{-5}$]*	*Least Significant Difference (LSD) at 5% level*	*Tukey's grouping for comparison*
Tempering temperature			
250°C	*3.8898*	*0.3232*	*G*
300°C	*3.9698*		*FG*
350°C	*4.2135*		*EF*
400°C	*4.3857*		*DE*
450°C	*4.5793*		*CD*
500°C	*4.8973*		*C*
550°C	*5.5692*		*B*
Un-treated	*6.7236*		*A*
Speed [min^{-1}]			
50	*5.3149*	*0.2285*	*A*
100	*4.8009*		*B*
150	*4.5163*		*C*
200	*4.4820*		*C*

Table 5. Two factor interaction effect on wear rate

Interaction of tempering temperature and speed [min^{-1}]	*Average wear rate [$g \cdot m^{-1} \times 10^{-5}$]*	*Least Significant Difference (LSD) at 5% level*	*Tukey's grouping for comparison*
250 × 50	*4.371*	*0.647*	*EFGHI*
250 × 100	*3.906*		*GHI*
250 ×150	*3.676*		*HI*
250 × 200	*3.606*		*I*
300 × 50	*4.446*		*EFGHI*
300 × 100	*3.969*		*GHI*
300 × 150	*3.718*		*HI*
300 × 200	*3.746*		*HI*
350 × 50	*4.752*		*EFGHI*
350 × 100	*4.323*		*EFGHI*

350 × 150	*3.920*		*GHI*
350 × 200	*3.858*		*GHI*
400 × 50	*4.955*		*DEFGH*
400 × 100	*4.488*		*EFGHI*
400 × 150	*4.092*		*FGHI*
400 × 200	*4.008*		*GHI*
450 × 50	*5.134*		*CDEFG*
450 × 100	*4.631*		*EFGHI*
450 × 150	*4.278*		*EFGHI*
450 × 200	*4.274*		*EFGHI*
500 × 50	*5.359*		*CDEF*
500 × 100	*4.894*		*DEFGH*
500 × 150	*4.687*		*EFGHI*
500 × 200	*4.648*		*EFGHI*
550 × 50	*6.120*		*ABCD*
550 × 100	*5.495*		*BCDE*
550 × 150	*5.350*		*CDEF*
550 × 200	*5.312*		*CDEF*
Un-treated × 50	*7.381*		*A*
Un-treated × 100	*6.702*		*AB*
Un-treated × 150	*6.408*		*ABC*
Un-treated × 200	*6.403*		*ABC*

Field evaluation. In field experiment, it was observed that oil palm harvesting knives quinched and tempered at a temperature of 250°C after austenizing gave the minimum wear rate of 2.288 g·ha^{-1}, which is significantly different from that of control treatment (Tab. 6). However, the heat treatment process of quinching and tempering at a temperature of 300°C after austenizing also exibited similar wear resistence behaviour with a comparable wear rate of 2.402 g·ha^{-1}. Further increase in tempering temperature augmented the wear rate in oil palm harvesting knives. During field evaluation at oil palm planation, Pedavegi, it was found that harvesting of oil palm by using improved knife takes 35 to 40 minuted less time than that of traditional knife , which implies that a saving of 16 % time was achieved (Tab. 6) for harvesting the same number of plants.

Table 6. Wear rate of different heat treated oil palm harvesting knife in field

Treatment	*Mean wear rate [g·ha^{-1}]*	*SEM*	*Duncan's Rank*	*Average time saving in comparision to control [%]*
250℃	*2.288*	*0.003*	*B*	*16.00*
300℃	*2.402*	*0.001*	*B*	*15.00*
350℃	*2.955*	*0.004*	*BA*	*11.50*
400℃	*3.470*	*0.002*	*BA*	*11.00*
450℃	*5.015*	*0.000*	*BA*	*10.50*
500℃	*4.919*	*0.005*	*BA*	*09.50*
550℃	*5.034*	*0.002*	*BA*	*09.00*
(control)	*5.691*	*0.006*	*A*	*0.00*
LSD at 5%	*2.8706*			

CONCLUSIONS

The wear rate decreases with sliding distance and obtained a steady state condition after 1800 m, irrespective of tempering temperature and sliding speed. For achieving maximum resistance to abrasive wear in the material and enhancement in service life of oil palm harvesting knife, heat treatment with tempering temperature of 250℃ for 90 minutes gives best results both in laboratory as well as under field conditions. This study further reveals that use of improved knife increases work efficiency by 16 percent.

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IZBOR MATERIJALA I CIKLUS KALJENJA RADI SMANJENJA HABANJA NOŽEVA ZA BERBU

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Sažetak: Berba palmi je naporan i intenzivan postupak. Problem je izraženiji zbog nedostatka odgovarajućih alata. Noževi koji se koriste se uvoze ili ih izrađuju lokalne zanatlije od otpadnog gvožđa. Ovde su ispitivani noževi uvezeni iz Malezije i noževi lokalne proizvodnje, a određivan im je hemijski sastav i tvrdoća. Na osnovu rezultata izabran je srednje ugljenični čelik za izradu noževa. Za dobijanje različitih kombinacija mikrostrukture, mehaničkih osobina i otpora habanju ovi noževi su grejani i naglo hlađeni na različitim temperaturama (od 250 do 550°C u intervalu od 50°C). Otpor ovog čelika na abrazivno habanje pre i posle kaljenja je ispitivano u laboratoriji upotrebom abrazivnog testa sa suvim peskom prema standardu *ASTM G 65*, sa različitim brzinama rotacije gumenog točka, od 50 do 200 min^{-1} u intervalu od 50 min^{-1}. Ispitivanjem je utvrđeno da su oba faktora, temperature kaljenja i brzina rotacije gumenog točka, imala značajan uticaj na otpor abrazivnom habanju. Na temperature od 250°C dobijeni su maksimalna tvrdoća i otpor habanju u laboratorijskim uslovima. Sličan otpor habanju uočen je i u poljskim uslovima, kada su noževi korišćeni za ručno sečenje lišća i grana.

Ključne reči*: stepen habanja, čelik, kaljenje, mehaničke osobine, berba*

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MONITORING PAŠNJAKA ZAPADNO-KAZAHSTANSKE OBLASTI (primer Karatobinskog rejona)

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Sažetak: Predmet istraživanjarada su pašnjaci Karatobinskog rejona Zapadno-Kazahstanske oblasti koji čine deo pustinja i polupustinja Kaspijske nizije-ravnice. Takođe, u radu su razmotreni i procesi degradacije pašnjaka uzrokovanih intenzivnom privrednom aktivnošću. U radu je na osnovu rezultata geoinformacionih istraživanja iznet stepen degradacije pašnjaka na oglednom poligonu Karatobe, Zapadno-Kazahstanske oblasti. Dobijeni parametri omogućavaju brzu i tačnu ocenu stanja pašnjaka u regionu.

Ključne reči: *monitoring, pašnjaci, dekodiranje, satelitski snimak, degradacija, profil, pesak, vegetacija.*

UVOD

U zapadnom delu regiona Karatobe prisutna je umerena do jaka degradacija pašnjaka uzrokovana nekontrolisanom ispašom stoke. Višegodišnja nekontrolisana

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Rezultati istraživanja su proizašli iz: Ugovora broj 117/1 o saradnji između Zapadno-Kazahstanskog agrarno tehničkog Univerzitet "Žangiri Han" i Poljoprivrednog fakulteta Univerziteta u Beogradu i iz aktivnosti po projektu TR 310 51, pod pokroviteljstvom Ministarstva obrazovanja i nauke Republike Kazahstan i Ministarstva prosvete, nauke i tehnološkog razvoja RS.

eksploatacija prekinula je razvoj vegetacije na pesku i uzrokovala je njenu nestabilnost, te je stoga na tim površinama prisutna korovska vegetacija ili uopšte i nema bilo kakve vegetacije, samo čist pesak [1].

Površine pod peskom u južnom delu Zapadno-Kazahstanske oblasti: Bokejordinskom, Žangalinskom i Karatobinskom rejonu za poslednjih 10 godina su se udvostručile i prostiru se na 56.000 ha. U Žangalinskom rejonu peskom su prekrivena naselja Koktau i Kazarma, a takođe je ugroženo i naselje Muhor. Početkom 1992 godine površine degradiranih zemljišta su se stabilizovale u intervalu od 9688,7-11939,6$\cdot 10^3$ ha, od toga su površine erodiranih zemljišta na nivou od 1118,7-2146,5$\cdot 10^3$ ha, zemljišta izložena vodenoj eroziji od 622,2-639,5$\cdot 10^3$ ha. Po podacima državnog katastra Zapadno-Kazahstanske oblasti, slana zemljišta se prostiru na oko 1430,8$\cdot 10^3$ ha, solonec i njemu slična na 7276,2-7406,3$\cdot 10^3$ ha, ilovasta na 714,0$\cdot 10^3$ ha i peskovita na 2511,0 $\cdot 10^3$ ha [9].

U Zapadno-Kazahstanskoj oblasti danas se uočava intenzivna antropogena aktivnost na prirodnu sredinu. U tom kontekstu pitanja efikasnog upravljanja suvih oblasti imaju važan značaj u cilju dostizanja održivog korišćenja prirodnih resursa. Aridni pejzaži su vrlo osetljivi na različite antropogene uticaje, te bi neracionalno gazdovanje uništilo ekosistem. Dakle, neophodna je pažljiva analiza svih ekoloških uslova kako bi se mogla obavljati poljoprivredna proizvodnja u ovim rejonima.

Zapadno-Kazahstanska oblast nalazi se na severozapadu Republike Kazahstan. Reljef teritorije je ravničarski, pri čemu se nadmorska visina smanjuje sa severoistoka oblasti na jugozapad sa 140 m na 15 m. Zemljišta su u tipu glinastih, tamno kestenasta, kestenasta i svetlo kestenasta i tipa soloneca. Vegetacija je uglavnom predstavljena kombinacijama: žitarice-trava, žitarice-pelen i pelen-pšenična trava. U južnom delu preovlađuju smeđa zemljišta i soloneci kao i delovi peskovitih tipova. Klima oblasti je kontinentalna.

Progresivna dezertifikacija i degradacija zemjišta Zapadnog Kazahstana uslovljena je razvojem dva procesa koja su u direktnoj vezi sa privrednom aktivnošću čoveka, to su: degradacija vegetacije i degradacija zemljišta [1,7 i 8]. U ovom rejonu je značajno manji uticaj antropogene dezirtifikacije, koja je uzrokovana tehničkim sredstvima pri izgradnji rudnika, bunara, industrijskih objekata, puteva, kao i "off road" transportom. Ipak svi ovi uticaji dovode do potpunog uništenja veoma krhkog aridnog ekosistema. Duge suše kao i nekontrolisana ispaša stoke takođe narušavaju i degradiraju zemljište u ovoj oblasti. Imajući u vidu sve navedeno, kao objekat praćenja izabran je Karatobinski rejon koji se nalazi na jugoistoku oblasti.

Cilj istraživanja je utvrđivanje stepena degradacije pašnjaka primenom geoinformacionih tehnologija na osnovu satelitskih snimaka na primeru poligona koji se nalazi u Karatobinskom rejonu Zapadno-Kazahstanske oblasti.

MATERIJAL I METODE RADA

Rejon se nalazi u severoistočnom delu Kaspijske nizije gde se takođe nalaze i peščare Narinkuma i Akum sa površinom od 10.000 km^2. Centralna i južna oblast su ravničarski predeo, a severna, blago talasast predeo. Kroz rejon protiče reka Kaldigajti (ukupne dužine 242 km, a u rejonu 130 km). Ukupna površina jezera u rejonu je 36,5 km^2 od toga slatkovodna zauzimaju površinu 6,8 km^2. Kao i cela Zapadno Kazahstanska oblast, površina rejona je deo severnog dela duboke Kaspijske depresije. Tokom paleozoita nije bilo znakova da će ova zona postati nezavisna geološka jedinica te je ona danas sastavni deo evropskog kontinenta, ali tokom vremena su se desile veoma složene geološke promene. Rezultat tih promena su podizanje i spuštanje delova terena, a supstrat je sastavljen od starih i mlađih morskih sedimentnih naslaga koji potiču još iz trias perioda mezozoika [10].

Reljef rejona: na jugoistoku se proteže Istočno Evropska nizija koja zazima i površinu Poduralskog platoa, kao i Uralske nagnute terene, a severni deo rejona je Kaspijska nizija. Površina rejona se smanjuje od severoistoka na jugozapad.

Rejon se nalazi u dve klimatske zone: na severu je zona gde je klima umereno kontinentalna i nedovoljno vlažna, a na jugu je zona umereno kontinentalne suve klime sa toplim letnjim periodima [10].

Zemljišta rejona se odlikuju velikom raznolikošću, koja je u vezi sa čestom promenom uslova geneze zemljišta. Međutim u delovima Karatobinskog rejona u slivnim područjima izraženi su zonalni tipovi zemljišta. Najrasprostranjenije su površine brdskih peščanih masiva Karagandikum i Kokuzekum. U plavnim zonama reke dominiraju ilovasta, supeščana i peščana zemljišta kao i aluvijumi koja imaju različit stepen saliniteta i alkalnosti. Pored njih tu su još i tamno kestenjasta zemljišta [10].

Pri sprovođenju geoinformacionog monitoringa u oceni degradacije pašnjaka za osnovu je uzeta „ВНИАЛМИ“ (Ruski naučnoistraživački agro-šumski meliorativni institut) metoda [3]. Degradacija je uglavnom prisutna na pašnjacima gde je na satelitskim snimcima površina istih, karakteristično svetlo sive boje [4] (Sl. 1). Snimljene površine pejzaža omogućavaju da se napravi preliminarna konturna karta-mapa stanja pašnjaka. Za ocenu stanja pašnjaka koristi se metod „poligona sa karakterističnim elementima pejzaža“. Pri tome pod poligonom se podrazumeva ograničena teritorija tipična za dati rejon po fizičko-geografskim uslovima i vrstom antropogenog uticaja u korišćenju prirodnih resursa. Na poligonu se biraju ključne (test) oblasti, koje treba da sadrže detaljne i statistički značajne, različite elemente travne vegetacije pašnjaka, neophodne za pouzdanu identifikaciju, a na osnovu kojih se daje karakteristika i ocena njihovog stanja.

Pejzažno-ekološko profilisanje jedna je od osnovnih metoda poljskih istraživanja za dobijanje pouzdanih rezultata u agro-šumskoj meliorativnoj kartografiji. Sveobuhvatni profil predstavlja horizontalni i vertikalni odnos svih komponenti pejzaža na teritoriji, njihov razmeštaj i karakteristike. Veličina razmere profila zavisi od skale i tematskih elemenata kartografije. Važno je da profil opisuje svaki prirodni kompleks sa najtipičnijom karakteristikom. [3 i 5].

Primena aerokosmičke metode bazirana je na snimcima površine zemlje iz aviona, helikoptera, kosmičkih brodova i veštačkih zemljinih satelita i ona daje nove mogućnosti za izučavanje i kartografiju prirodnih komponenata. Ova metoda omogućava da se utvrdi tačan geografski položaj ispitivanih objekata i procesa, kao i da se utvrde kvantitativne i kvalitativne biogeofizičke karakteristike istih [2 i 6]. Danas, za rešavanje naučnih i praktičnih zadataka su neophodni računari koji omogućavaju brzu i pouzdanu obradu podataka i svih drugih potrebnih informacija. Holistički pristup agro-pejzažu i antropogenim procesima može dati kartografski prikaz primenom savremenih geoinformacionih sistema (GIS), koji obezbeđuju prikupljanje, čuvanje, obradu podataka, mapiranje i manipulaciju istih, kao i dobijanje novih informacija-događaja sa koordinatama, nakon obrade podataka [11,12]. Na primer, za implementaciju fitomeliorativnih radova na velikom prostranstvu Kaspijskih pustinja i polupustinja, potrebne su nove detaljne operativne informacije o njihovom fitomeliorativnom potencijalu, a one se mogu dobiti primenom „daljinskih“ i prevashodno aerokosmičkim metodama [3].

Dakle, geoinformaciona ocena satelitskih snimaka sprovedena je primenom kompjuterske tehnologije i programa *GlobalMapper* i *AutoCad*. Primena ove metode dozvoljava da se u kratkom vremenskom intervalu da ocena stanja pašnjaka degradiranih zemljišta.

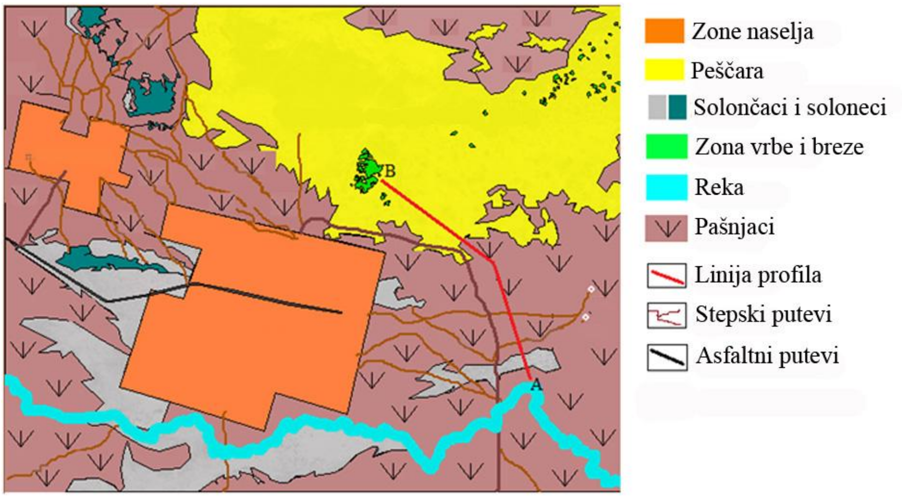
REZULTATI ISTRAŽIVANJA I DISKUSIJA

U radu je načinjena kosmokarta pomenutog poligona uz pomoć programa *GlobalMapper*. Koordinate poligona su 49°41'02" severne geografske širine i 53°32'33" istočne geografske dužine (Sl. 1).

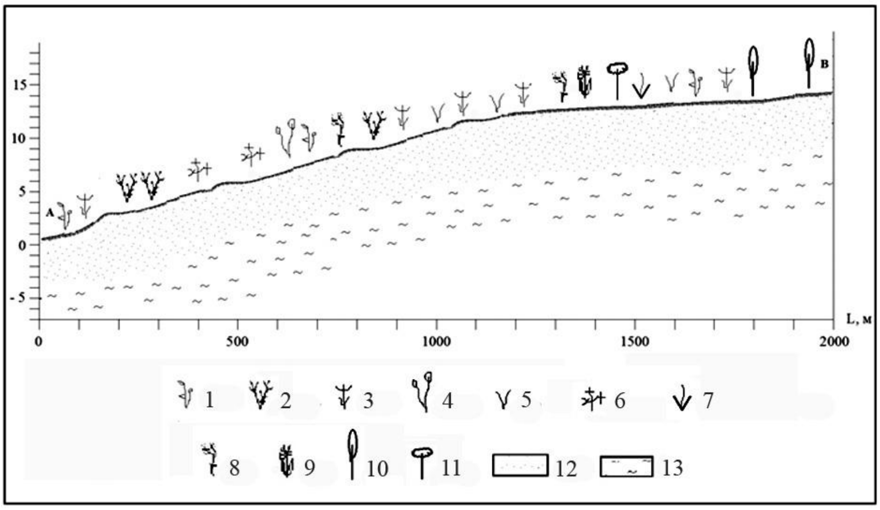
Slika 1. Satelitski snimak analiziranog rejona Karatobe, Zapadno Kazahstanske oblasti
Figure 1. Satellite image of the analyzed regions Karatobe, Western Kazakhstan area

Uz pomoć GIS-a i pomenutih programa, satelitski snimak je dekodiran za dalja istraživanja (Sl. 2). Za dekodiranje snimka je korišćeno pejzažno-ekološko profilisanje. Kao rezultat toga dobijeni su i sačuvani kartografski podaci sa svim pratećim informacijama o vegetaciji na toj lokaciji.

Prilikom poljskih istraživanja na test poligonu dobijen je i ekološki profil (Sl. 3).



Sl. 2. Pejzažno ekološka shema test poligona u rejonu Karatobe
Fig. 2. Landscape environmental scheme test polygon in the Karatobe region



1 - Astragals	*7 - Calligonum aphyllum*
2 - Artemisia	*8 - Ceratocarpus*
3 - Euphorbiaceae	*9 - Agropyron*
4 - Astragals	*10 - Breza-Betula*
5 - Carex	*11 - Vrba-Salicacea*
6 - Alhagi pseudalhagi	*12 - Pesak-sand*
13 - Ilovača-clay	

Slika 3. Pejzažno-ekološki profil (AB) u rejonu Karatobe
Figure 3. Landscape ecological profile (AB) in the Karatobe region

Pejzažno-ekološki profil karakteriše svaki ekosistem sa njegovom najreprezentativnijom karakteristikom. U rejonu Karatobe dominiraju ilovače, peskovite ilovače i najčešće peščana svetlo-kestenjasta zemljišta. Takođe opis vegetacije vrši se po smernicama koje su u skladu sa zemljišnim geobotaničkim zapažanjima, koju karateriše ljudska aktivnost i stepen njenog uticaja na ekosistem [3]. U daljoj analizi opisan je uticaj fitoekoloških parametara na pejzažno-ekološki profil masiva. Profil se sastoji od 12 tačaka.

Tačka № 1. Koordinate su 49°41'02" severne geografske širine i 53°32'33" istočne geografske dužine. Profil počinje od obale reke Kaldigajti. Na datoj lokaciji urađen je zemljišni profil. U profilu nisu posmatrani (analizirani) oštri prelazi. Zemjlišni horizont od 0 до 50 cm je prožet biljnim korenjem, posle 50 cm se nalaze gnezda lasti. Horizont je pun pesak, po stepenu vlažnosti je suvi i svetlo sive je boje.

Biljnu vegetaciju čini zajednica Astragalus-Euphorbia *(Astragals-Euphorbia)*. Ukupan broj biljnih vrsta je 9. Dominantna biljna zajednica je iz porodice Mlečika (*Euphorbiaceae)* čija je visina 15 cm. Sodominant je višegodišnja travna biljka iz porodice mahunarki, Astragalus *(Astragals)*, visine 35 cm. Na datoj lokaciji vegetacija pokriva 10% teritorije. U toj bicenozi se sreću i Alisum *(Alyssum)*, Livadarka živorodna *(Pao bulbosa L.)* i *Ceratocarpus arenarius*, visine od 13-15 cm. Vegetativno pokriće na lokaciji je 7-8%. Pojedinačno mogu se naći Vlasulja (*Anisantha tectorum)*, Hajdučka trava *(Achillea)*, Ovas pustinjski *(Leymus racemosus)* i Šaš *(Carex)*. Njihovo vegetativno pokriće je 4-5%. Privredno se koriste kao pašnjačke površine. Stanje degresije pašnjaka se karakteriše kao jako degradirana-narušena površina.

Tačka № 2. Koordinate su 49°41'07" severne geografske širine i 53°32'36" istočne geografske dužine. Vegetaciju čini zajednica Belog pelina *(Artemisia absinthium)*. Visina osnovne mase biljka je 13-15 cm. Ukupan broj biljnih vrsta je 6. Ukupna pokrivenost teritorije je 13-15%. Iz porodice trava dominira Livadarka živorodna *(Pao bulbosa L.)*, sa visinom do 10 cm i prekrićem površine od 8-9%. Od jednogodišnjih trava tu je još i Vlasulja *(Anisantha tectorum L.)*, visine 15 cm i prekrićem od 5-6 %. Sporadično se mogu naći Alisum *(Alyssum)*, Mreževica *(Limonium)*, Šaš *(Carex)*, prosečne visine 25 cm i prekrićem površine od 4-5 %. Površine sa ovom vegetacijom spadaju u grupu srednje degradiranih pašnjaka.

Tačka № 3. Koordinate su 49°41'11" severne geografske širine i 53°32'42" istočne geografske dužine. Ova lokacija je otkrivena (nema travne vegetacije) i može se koristiti kao plato za deponije. Od trava na lokaciji može se sporadično naći samo Kamilji trn *(Alhagi pseudalhagi)* biljka iz familije mahunarki sa visinom do 17 cm. Zemljište se sastoji od brdskih peskova. Prekrivenost vegetacijom je 0%. Stadijum degresije ovih površina je vrlo veliki. To su zemljišta sa veoma izraženom degradacijom što se najbolje vidi na mestima veće koncentracije životinja, u blizini bunara, mesta skupljanja nomanskih stada ili seoskih naselja. Na tim lokacijama biljni pokrivač skoro da ne postoji.

Tačka № 4. Koordinate su 49°41'15,5" severne geografske širine i 53°32' 38,5" istočne geografske dužine. Biljna zajednica na ovoj lokaciji je iz porodica Livadarki i Astragalusa *(Pao bulbosa-Astragals)*.Visina osnovne travne mase je 12-15 cm. Ukupan broj biljnih vrsta je 8, a pokrivenost površine je 20 %. Dominantna biljka je Astragalus *(Astragals)*, sa visinom 13 cm i 15% prekrivenošću. Sodominant je Livadarka *(Pao bulbosa)*, visine 11 cm. sa prekrićem od 10%. U velikom broju su prisutne i biljke iz familije kupusnjača, Alisum *(Alyssum)*, visine 14 cm. Prostor između Astragalusa dopunjen je Alisumom. Beleži se sporadično pisustvo vegetacije iz porodice štireva *(Amaranthaceae)*, Loboda *(Atriplex)* i iz porodice trava (*Poaceae*), Pirevina *(Agropyron)* visine18 cm, sa prekrićem od 5%. Takođe tu je i Beli pelin *(Artemisia absinthium)* visine 13 cm, i višegodišnje trave iz porodice glavočika (*Asteraceae*), Čičak *(Carduus)*, visine 1 m. Biljna vegetacija na datoj lokaciji je raspoređena poput mozaika. Faza degresije pašnjaka je srednje degradirano stanje. Nakon ove lokacije dolazi površina pod nagibom. Od reke Kaldigajti do nagiba ima 500 m. Pokrivenost površine je 15 % zajednicom Livadarki i Astragalusa *(Pao bulbosa-Astragals)*. Visina glavne mase je 10-15 cm. Ukupan broj biljnih vrsta je 11. Dominantna biljka je Astragalus *(Astragals)*. Sodominant je Livadarka *(Pao bulbosa)*. U velikom broju su prisutne i biljke: Mlečika *(Euphorbia)*, Alisum *(Alyssum)*, *(Ceratocarpus arenarius)*, jednogodišnja zeljasta biljka Vlasulja *(Anisantha)* visine 10 cm i iz porodice glavočika, Hajdučka trava *(Achillea)*. Pokrivenost površine je 10%. Sporadično su prisutni i Pustinjski ovas *(Leymus racemosus)*, Šaš *(Carex)*. Pokrivenost površine je 5%. Faza degresije pašnjaka je srednje degradirano stanje.

Tačka № 5. Koordinate su 49°41'49" severne geografske širine i 53°32'14" istočne geografske dužine. Na ovoj lokaciji preovlađuje zajednica Ceratokarpusa, Mlečika i Pelina (*Ceratocarpus-Euphorbia-Artemisia*). Ukupan broj biljnih vrsta je 6. Pokrivenost površine je 10%. Visina osnovne mase je 15-20 cm. Dominantna biljka je Austrijski pelin *(Artemisia austiaca)*, visine 30 cm. Pokriva 9% površine. Sodominant je *(Ceratocarpus)*,visine od 14-15cm sa prekrićem od 7%, zatim Mlečika *(Euphorbia)*, visoka 15 cm koja pokriva 5-6% površine. Sporadično se sreću Vlasulja *(Anisantha tectorum)*, Alisum *(Alyssum)*, Šaš *(Carex)*, prosečne visine 15-18 cm. sa pokrivenošću površine 4%. Faza degresije pašnjaka je jako narušeno stanje.

Tačka № 6. Koordinate su 49°41'52" severne geografske širine i 53°32'10,5" istočne geografske dužine. Dominantna biljka je Mlečika *(Euphorbia)*, visine 13 cm. U travnjaku je izraženo prisustvo Šaša *(Carex)*, koji predstavlja dragocenu biljnu hranu i na površinama gde se on nalazi odvija se intenzivna ispaša. Ukupna prekrivenost je 10%. Faza degresije pašnjaka je jako degradirano-narušeno stanje.

Tačka № 7. Koordinate su 49°41'60" severne geografske širine i 53°32'06" istočne geografske dužine. Lokaciju nastanjuje zajednica Šaša i Mlečika *(Carex-Euphorbia)*, visine 15 cm sa prekrićem površine 10%. U velikom broju su prisutne i biljke: Pustinjski ovas *(Leymus racemosus)* visine 65 cm, sa prekrićem površine od 7%. Sporadično se sreću Alisum *(Alyssum)*, Beli pelin *(Artemisi alerchiana)*, Vlasulja *(Anisantha)* sa prekrićem 5-6%. Faza degresije pašnjaka je jako degradirano-narušeno stanje.

Tačka № 8. Koordinate su 49°41'24,5" severne geografeke širine i 53°32'09" istočne geografske dužine. Lokaciju prekriva zajednica Pirevine i Ceratokarpusa *(Agropyrum-Ceratocarpus)*. Ukupan broj biljnih vrsta je 6. Na ovoj lokaciji visina osnovne travne mase je 18-20 cm. Dominantna biljka ove tačke je *Ceratocarpus arenarius*, visine 13 cm sa prekrićem od 9-10%. Sodominantna biljka je iz porodice trava, Pirevina *(Agropyrum)*, visine 18 cm, sa prekrićem od 8%. Sporadično se susreću „Teresken" *(Ceratoides)*, visine 40 cm, sa prekrićem 3%. Takođe tu je i jednogodišnja zeljasta biljaka Vlasulja *(Anisantha)*, visine 10 cm, sa prekrićem 2-3%. To su jako degradirani pašnjaci.

Tačka № 9. Koordinate su 49°42'28,4" severne geografske širine i 53°32'13,6" istočne geografske dužine. Datu tačku prekriva porodica *Polygonaceae*, žbunovi heljde

(Calligonum aphyllum), potom porodica vrba *(Salicaceae)*. Područje se odlikuje plitkim nivoom podzemnih voda. Od trava su dominantne Mlečika *(Euphorbia)*, Šaš *(Carex)*, Austrijski pelin *(Artemisia austiaca)*. Prekrivenost površine je 20-25%. Sporadično se sreće i Livadskih raž *(Secale)*, visine 8 cm sa ukupnim prekrićem od 25%. Faza degresije pašnjaka je srednje narušeno stanje.

Tačka № 10. Koordinate su 49°41'49,2" severne geografske širine i 53°31'51,5" istočne geografske dužine. Na ovoj lokaciji se nalaze slabo obrasli-prekriveni peskovi. Ukupna prekrivenost vegetacijom je 10%. Preovlađuje zajednica Šaša i Astragalusa (*Carex-Astragalus*). Dominantna je biljka iz familije mahunarki, Astragalus *(Astragalus arenarius L.)* visine 10 cm. Sodominantna vegetacija je Šaš (*Carex*), visine15 cm, koja prekriva 9% površine. Sporadično se susreće zeljasta biljaka Vlasulja *(Anisantha)*, *Ceratocarpus arenarius*, Livadarka *(Poa bulbosa L.)*. Prekrivenost površine je 1-2%. Po stanju u kome se nalaze to su jako narušeni pašnjaci.

Sledeća tačka № 11, se nalazi na severoistoku rejona, koordinate tačke su 49°43'51,8" severne geografske širine i 53°32'52,5" istočne geografske dužine. Drvenastu vegetaciju lokacije čine breze. Dominantna u vegetaciji trava je Mlečika *(Euphorbia)*, visine 15 cm, koja pokriva 10% ukupne površine. U velikom broju su prisutne i biljke Šaš (*Carex*), Alisum *(Alyssum)*, Austrijski pelin *(Artemisia austiaca)*, Pelin pustinjski *(Artemisia arenaria)*. Sporadično se može naći i familija *rubiacea* i to Broćika-galium *(Galiumaparine)*, visine 30 cm. Po stanju u kome se nalaze to su jako degradirani pašnjaci.

Profil se završava tačkom 12, na koordinati 49°43'47,4" severne geografske širine i 53°32'59" istočne geografske dužine. Visina grede je 7 m. Od drvenstih biljaka tu su žbunaste vrbe i breze.Visina drveća je 3-4 m. Na vrhu nivoa je brojna kolonija Mlečika *(Euphorbia)*, visine 14 cm. Prekrivenost površine je 10%. Po stanju u kome se nalaze to su jako degradirani pašnjaci.

Primenom date metode u kratkom vremenskom intervalu i bez previše napora moguće je sprovesti monitoring stanja degradiranosti pašnjačkih površina.

ZAKLJUČAK

Rezultati istraživanja su pokazali da je neophodna izrada posebnih programa za sprečavanje degradacije zemljišta kao i za konsolidaciju već degradiranih i to primenom agro-šumskih meliorativnih radova. Preporučene mere bi trebalo da imaju sveobuhvatni karakter i da uzmu u obzir sve prirodno-klimatske i antropogene faktore. Primena ove metode snimanja satelitom, određene regije i analizom tih snimaka, na teritoriji Zapadno-Kazahstanske oblasti moguće je obezbediti konstantan monitoring stanja ciljnih objekata (površina), visok kvalitet i efikasnost tematskih karata rejona, za primenu agro-šumskih meliorativnih aktivnosti kao i visoku pouzdanost podataka o stanju pašnjaka posmatrane regije.

Osim toga kao što je već i poznato, intenzivnom ispašom se uništavaju prirodni pašnjaci, tj njihov travni pokrivač. Područja za ispašu nalaze se u blizini naseljenih mesta i bunara gde životinje u toku jednog dana nekoliko puta izgaze zonu u kojoj se nalaze. Na tim površinama vegetacija skoro da se na čisto uništi.

Detaljnom anlizom satelitskih snimaka i pejzažno-ekološkoim profilom prevashodno moguć je uvid u stanje pašnjaka na osnovu kog se može definisati način dalje eksploatacije tih površina. Ukoliko su procesi degradacije u poodmakloj fazi, a još uvek se mogu konsolidovati na tim površinama se radikalno menja eksploatacija od kontrolisane ispaše u blažoj varijanti do agro-šumskih meliorativnih radova. Ovi radovi u prvoj fazi podrazumevaju sadnju drvenastih biljaka kao što su tamariks (*Tamaricaceae)*, žbunaste vrbe i drugo žbunasto bilje, a sve u cilju konsolidacije peščanih površina.

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MONITORING OF THE PASTURES IN THE WEST-KAZAKHSTAN REGION (Example from the Karatobin region)

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***Abstract**:* Topic of this research are pastures in the Karatobin region that are parts of the Kaspijan valley desert and semi-deserts. In this paper degradation of the pastures, caused by industry activities is analyzed. Based on the results obtained from the geo-information research, the degree of pasture degradation in the experimental field of Karatobe (West-Kazkhstan region) is given. Obtained results give the possibility for easy and precise evaluation of the pasture conditions in the region.

***Key words**: monitoring, pastures, decoding, satellite images, degradation, profile, sand, vegetation.*

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PULL, TORQUE SLIP CHARACTERISTICS OF BRAKED WHEEL OF SEED DRILLS AND PLANTERS

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Abstract: Sowing or planting is one of the most important farm operations. Generally it is done by seed drill and planters. Metering device govern the seed to seed spacing in sowing operation. A constant velocity ration between the ground wheel shaft and the shaft of metering device helps in maintaining regular hill to hill spacing. Metering device requires torque for its operation which is derived from the ground wheel. Therefore, the ground wheel in seed drills and planters works as a braked wheel. The braked wheel experiences negative slip which is known as skid. Excessive value of skid will result in alteration of spacing between hills. Skid increases with the increase in braking torque resulting in large variations in hill to hill spacing. Hence, the relationship between braking torque and skid is important to the designer of seed drills and planters. The relationships between pull, torque and slip characterizes the behavior of the braked wheel. An experiment was carried out to determine skid at different lug height (15, 20, 25, 30, 35 and 40 mm), different axle load (98.1, 147.15 and 196.2 N) and different torque. A regression model was developed relating skid (s) with lug height (L) and torque (*T*). Axle load had no significant effect on skid in the range studied. The regression model was a quadratic polynomial equation having (R^2 = 0.82). Expected value of skid at different values of lug height and braking torque were calculated from the regression equation and given in a table. This can be used for determining lug height when torque requirement and permissible level of skid were known. It can be seen that skid increases with decrease in lug height almost for all values of braking torque.

Key words: *pull, torque, skid, axle load and ground wheel*

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INTRODUCTION

In any crop production program sowing or planting is one of the most important farm operations. Traditional sowing methods include broadcasting manually, opening furrows by a country plough and dropping seeds by hand and dropping seeds in the furrow through a bamboo or metal funnel attached to a country plough. Generally dibbling is practiced for sowing in small areas. Multi row traditional seedling devices with manual metering of seeds are quite popular with experienced farmers. Traditional sowing methods results in non-uniformity in distribution of seeds and poor control over depth of seed placement. Proper placement of seeds and fertilizers enhances productivity [1].

The basic objective of sowing operation is to put the seed and fertilizer in rows at desired depth and seed to seed spacing, to cover the seeds with soil and to provide proper compaction over the seed. Improved seed-cum-fertilizer drills are provided with seed and fertilizer boxes, metering mechanism, furrow openers, covering devices, ground drive system and a set of controls for variation of seed and fertilizer rates. The major difference in the different designs of seed drills and planters is in types of seed and fertilizer metering devices and in types of furrow openers [1].

Power required for operating the metering devices is taken from transport wheel, transport-cum-depth gauge wheel, press wheel and float type ground wheel. In case of tractor operated machines, power is taken from PTO shaft of tractor, transport-cum-depth gauge wheels and floated type ground wheel. The type of drive wheel to be used on drills depends on the ground conditions [9].

Metering device govern the seed to seed spacing in sowing operation. The metering devices of seed drills and planters draw the power required for their operation from the ground wheels. Wheels are of iron and closed type for better traction. This ground wheel or drive wheel is attached to the frame in front of the implement. A constant velocity ratio between the ground wheel shaft and the shaft of metering device helps in maintaining regular hill to hill spacing.

Rate of seeding with the fluted wheel in bulk flow seed metering devices is controlled by moving the wheel axially to change the length of flutes exposed to the seed in the feed hopper [9]. Primary method of controlling the seed rate with double-run feed is by changing the speed ratio between the ground wheels and the feed shaft. Power from ground wheel is transmitted to a shaft mounted on front frame. Power transmission unit consists of drive wheel, shaft, idler, sprocket and roller chain. From this shaft power is transmitted to seed and fertilizer metering shafts through chain and sprocket arrangement. However, size of roller chain and sprocket can vary in different models. The idler has been provided to tighten or loosen the chain for its smooth running.

The ground wheel in seed drill or planter works as a braked wheel. A braked wheel experiences skid which is known as negative slip. Excessive value of skid will alter spacing between hills. Metering device requires torque which is provided by the ground wheel. When braking torque increases skid also increases, due to skid hill to hill spacing will vary. The forward speeds of the experiment were taken 3 to 5 $km \cdot h^{-1}$ [7]. The relationship between braking torque and skid is important for design of the power transmission. The relationships between pull, torque and slip of the braked wheel will be useful for designers of seed drills and planters.

Keeping the above facts in mind a study was undertaken to determine the effect of lug size on slip characteristics of a braked lugged wheel. The purpose of this study was to determine the effect of lug height, axle load and braking torque on the skid experienced by the lugged rigid wheel.

MATERIAL AND METHODS

Experimental Method and Materials. The experimental setup used in this study is shown in Fig. 1(a) and (b). The dimensions of testing of wheel lugs were same as the dimension of zero till seed drills drive wheel lug. Because of traction requirement in both equipment's are similar. The lug heights of testing wheel were varied from 40-15 mm at 5 mm interval (40, 35, 30, 25, 20 and 15 mm). Lug width is equal to rim width. Total 16 numbers of lugs are attached at 22.5 degree angle on the testing wheel. Material used for lug is mil steel.

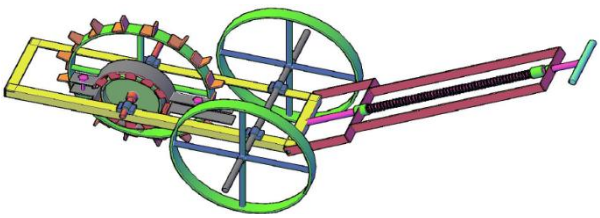

Figure 1. Isometric view of braked wheel test setup

Development of Test Setup. The main objective of this test was to determine an optimum lug size of rigid braked wheel for given field condition. Lugs of different heights were prepared for the purpose of testing. The lug height was varied between 40, 35, 30, 25, 20, 15 mm in steps of 5 mm. The test setup consisted of test wheel, prony brake dynamometer, support wheels (two), handle bracket and spring, frames and dead weights.

Pictorial views of the braked wheel test setup is given in Fig. 1 (a & b) and a photograph of the same is given in Fig. 2. The spring measuring the pull was calibrated by measuring its deformation under static load applied through dead weights.

Experimental Method. The performance of lugged wheel used as ground wheel in seed drills and planters evaluated at 6 different lug heights (15,20,25,30,35 and 40 mm), four different braking torque and three different loading condition (98.1 N, 147.15 N and 196.2N). The load coming on the axle of the braked wheel including weight of the wheel and axle was 348N (35.5 kg). The experimental details are shown in Table 1. The lugged wheel was installed in a test setup and the test setup was pulled by a man. The magnitude of pull is measured by deflection in a calibrated spring and the braking torque is measured by a digital scale installed at the arm of brake drum. The lugged wheel setup was tested in the Experimental Farm of Agricultural and Food Engineering Department, IIT Kharagpur. The experiment was conducted with three replication and pull, torque and skid were measured. In this study torque, lug height and normal load on axle were taken as independent parameters where as pull and skid (negative slip) were taken as dependent parameters. The value of average cone index for first and second field were measured and reported separately.

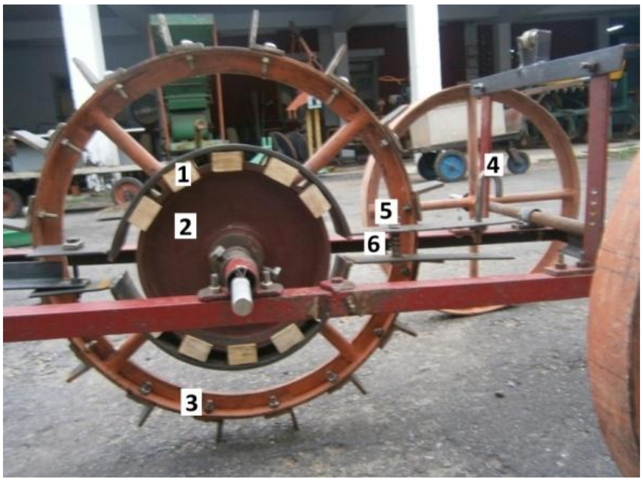

Figure 2. Photograph of braked wheel test setup
1. Wooden brake shoe, 2. Brake drum, 3. Testing wheel attached with iron lugs, 4. Hinge, 5. Bolt, 6. Load bar with compression spring

Table 1. Independent and Dependent Parameters in Testing of Braked Wheel

Independent variables	*Lower limit*	*Upper limit*	*Levels*	*Values*
Lug height [mm]	*15*	*40*	*6*	*15, 20, 25, 30, 35, 40*
Axle load [N]	*98.1*	*196.2*	*3*	*98.1, 147.15, 196.2*
Torque [N·m]	*Corresponding to 0 to 20% skid*	-	-	-
Dependent variables	*Skid (%)*		*Pull (kg)*	
Replications	*3*			

Experimental Procedure. The experiments were conducted in the Experimental Farm of Agricultural and Food Engineering Department. Each experiment was conducted on 15×15 m area.

For conducting the test following steps were adopted:

1. Experimental field was selected and measured.
2. Experimental field was prepared ploughing with a mould board plough followed by one pass of cultivator, two passes of disc harrow and one pass of leveler.
3. Cone index of the field was measured by cone penetrometer.
4. The value of torque, pull, forward speed and skid were recorded simultaneously.
5. For measuring skid the method used was the distance travelled method.
6. For measuring skid the method used was the distance travelled method. The theoretical distance was calculated from the rim diameter without lug. For actual distance we pull the trolley and measured the distance along with number of revolution of testing wheel.

$$Slip\ (\%) = (dt - da) \cdot dt^{-1} \cdot 100 \tag{1}$$

where:

dt [-] - theoretical distance travelled for a given number of revolutions,
da [-] - actual distance travelled for a given number of revolutions.

For braking torque the distance from the centre of the wheel to the lever end was multiplied by the force (kg) read from the scale.

Equation for the calculation for braking torque:

$$T = 9.81 \cdot M \cdot r \tag{2}$$

where:

M [kg] - mass on hanger,
r [m] - distance from centre of flywheel to hanger,
T [N·m] - torque applied.

Pull was measured by noting down the deformation of spring on the handle bar. The angle θ of the handle from horizontal at the time of pull was also measured (θ = 43.56°). Lugs of different height were fitted on the test wheel during the test. Photographs taken during conduct of the test are shown in Fig. 3.

Figure 3. Figure of testing of braked wheel in field conditions

RESULTS AND DISCUSSION

The main purpose of the study was to design the ground wheel of the seed drills and planters and to find the lug height for ground wheel at maximum braked torque at minimum skid. Proving ring was calibrated first. Afterwards methodology was adopted for the rim diameter and rim width from the seed drill and planters for test setup at six different lug heights (15-40 mm) at 5 mm interval. Optimized power requirement is needed for metering mechanism from ground wheel in which lug height having skid within 3-10 %. Optimization was done with respect to the response surface plot obtained from the experiment. Variance analysis was done after that to test the adequacy of the model.

Calculation of cone index. We have data for deflection of gauge reading with depth of penetration of cone penetrometer. The cone index was calculated by formula:

$$Cone\ Index = \frac{m \times deflection \times 9.81 \times 1000}{323} \tag{3}$$

The value of cone index measured at two plots of the field are given in Tab. 2. Cone Index of the first plot (*KPa*) 916.66 and of the second plot (*KPa*) 888.3.

Table 2. Soil properties of the experimental site

Depth [cm]	*Sand [%]*	*Silt [%]*	*Clay [%]*	*EC [at 20 ms]*	*Available N [kg·ha^{-1}]*	*Available K [kg·ha^{-1}]*	*Available P [kg·ha^{-1}]*	*pH in water*
5	*62.5*	*24.2*	*24.2*	*0.3*	*178*	*123*	*16*	*6.1*
20	*59.6*	*20.4*	*20.4*	*0.5*	*150*	*89*	*15*	*6.2*
40	*55.4*	*22.4*	*22.4*	*1.6*	*100*	*75*	*14*	*6.7*
60	*52.4*	*20.2*	*20.2*	*0.3*	*84*	*44*	*12*	*6.9*
80	*48.4*	*21.2*	*21.2*	*0.2*	*78*	*56*	*4*	*6.7*

Response Surface Model and ANOVA Analysis. The values of skid at different lug height and torque were analysed using ANOVA given in Fig. 5. A response surface model showing the interaction between torque and lug height corresponding to skid was developed. This is shown in Fig. 6. Regression model developed relating skid (*s*) with lug height (*L*) and torque (*T*) was shown in Eq. (4). The quadratic polynomial equation was developed for skid as a function of lug height and torque. The developed regression equation describes the relation among *s*, *T* and *L* with high correlation coefficient (R^2 = 0.82) depicting that almost 80% of the data are within the acceptable limit. Difference between actual and predicted response was not so widely spread. The model can be well accepted with more or less satisfactory correlation coefficient ($R^2 > 0.8$).

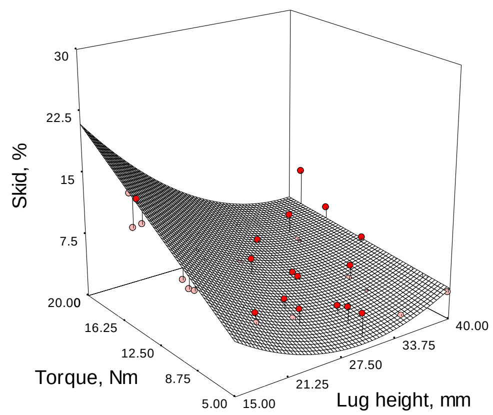

Figure 5. Response surface plot of torque, lug height and skid

At minimum value of braking torque if lug height was increased, skid was decreased up to 30 mm lug height value and after that skid started to increase with braking torque again. At 15 mm minimum lug height braking torque increased with skid rapidly. At the maximum lug height of 40 mm variation in torque with skid was little yielding a straight line with insignificant slope at *T-s* plane in Fig. 6. At 35 and 30 mm lug height, the corresponding braking torque increased with minimum variation in skid. But after 15, 20 and 25 mm lug height, increase in braking torque was not constant with respect to the increase in skid value. The recommended skid was within 3-10% at the highest braking torque. The criteria was fully satisfied at 40 lug height condition.

The contour plot given in Fig. 6. confirmed the presence of opposite sign of the coefficients of $L \times T$ and L^2 which suddenly change the direction of iso skid line at higher values of torque (> 14 N·m) and lug height (> 30 mm).

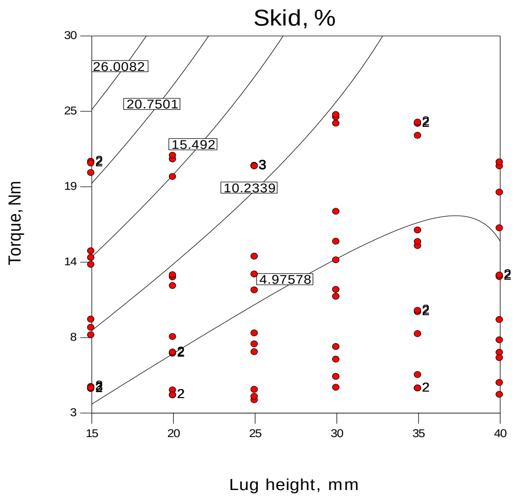

Figure 6. Contour plot of skid different values of lug height and torque

Table 3. ANOVA table for regression model on skid of braked wheel (with significant and insignificant values)

Source	*Sum of squares*	*df*	*Mean square*	*F-value*	*P-value*	
Model	*1924.35*	*9.00*	*213.82*	*37.90*	*< 0.0001*	*Significant*
L	*694.64*	*1.00*	*694.64*	*123.13*	*< 0.0001*	*Significant*
N	*21.15*	*1.00*	*21.15*	*3.75*	*0.0574*	*Insignificant*
T	*741.07*	*1.00*	*741.07*	*131.36*	*< 0.0001*	*Significant*
L.N	*3.06*	*1.00*	*3.06*	*0.54*	*0.4641*	*Insignificant*
L.T	*245.51*	*1.00*	*245.51*	*43.52*	*< 0.0001*	*Significant*
N.T	*15.07*	*1.00*	*15.07*	*2.67*	*0.1072*	*Insignificant*
L^2	*206.73*	*1.00*	*206.73*	*36.64*	*< 0.0001*	*Significant*
N^2	*10.27*	*1.00*	*10.27*	*1.82*	*0.1822*	*Insignificant*
T^2	*2.41*	*1.00*	*2.41*	*0.43*	*0.5158*	*Insignificant*
Residual	*349.77*	*62.00*	*5.64*			
Total	*2274.12*	*71.00*				

Analysis of variance of the above regression relationship is given in Tab. 3. It can be seen that the fitted model as well as the constituent terms (L, T, $L \times T$ and L^2) where significant. Load on the axle (N) was found to be non-significant at 5% level of significance. The quadratic terms of N and T are insignificant (p>0.05) to the model along with the interaction term of L and T. The relationship between values predicted by the above empirical relationship by Eq. 4 and the measured value are shown in a plot given in Fig. 5. It can be seen that the above empirical relationship can be used to predict the skid satisfactorily.

Based on the ANOVA shown in Tab. 2 an empirical relationship was developed using significant terms. The empirical relationship obtained is given below.

$$s = 16.48401 - 1.41666L + 1.52887T - 0.035443L.T + 0.027153L^2 \quad (R^2 = 0.82) \tag{4}$$

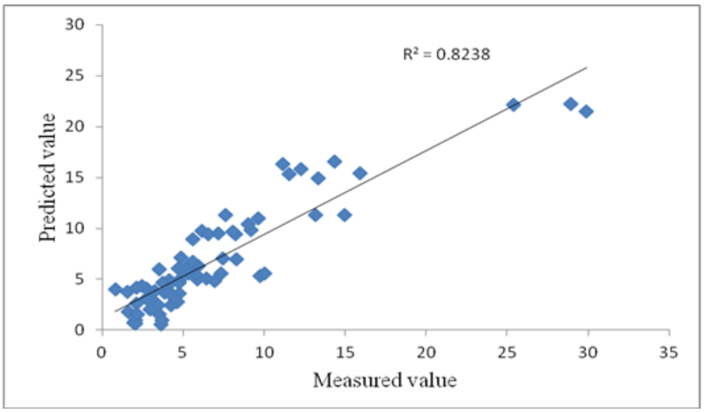

Figure 7. Plot of measured skid against the predicted value of skid by response surface model

Expected value of skid at a different lug height and braking torque calculated from Eq. 1 are tabulated in Tab. 4. It can be seen that skid increases with decreasing lug height almost for all values of braking torque, this table can be used to select lug height for a given braking torque with in an expectable level of skid.

CONCLUSIONS

Field experiment was carried out to study the torque, pull and skid characteristics of ground wheel, used in seed drill and planters. An experiment was carried out to determine skid at different lug height and torque and a regression model was developed. Based on the analysis the following conclusions were drawn.

1. Regression model developed relating skid with lug height and torque. The quadratic polynomial equation was developed for skid as a function of lug height and torque. The developed regression equation describes the relation among skid, torque and lug height with high correlation coefficient (R^2 = 0.82).
2. At minimum value of braking torque if lug height was increased, skid was decreased up to 30 mm lug height value and after that skid started to increase with braking torque again.
3. At 35 and 30 mm lug height, the corresponding braking torque increased with minimum variation in skid. But after 15, 20 and 25 mm lug height, increase in braking torque was not very constant with respect to the increase in skid value.
4. Expected value of skid at a different lug height and braking torque calculated from Eq. 1 are tabulated in Tab. 5.3. It can be seen that skid increases with

decreasing lug height almost for all values of braking torque, this table can be used to select lug height for a given braking torque with in an expectable level of skid.

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KARAKTERISTIKE VUČE, OBRTNOG MOMENTA I KLIZANJA KOČENOG TOČKA SEJALICA I SADILICA

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Sažetak: Setva ili sadnja su među najvažnijim operacijama u poljoprivredi. Merni uređaj na sejalici ili sadilici određuje rastojanje između zrna. Konstantan odnos brzine vratila pogonskog točka i vratila mernog uređaja održava pravilno rastojanje između sadnica. Merni uređaj zahteva pogonski obrtni moment od pogonskog točka. Zato pogonski točak pri trenju sa podlogom radi kao kočeni točak. On trpi negativno klizanje poznato kao klizno kočenje. Porast vrednosti prokljizavanja dovodi do promene rastojanja između sadnica. Povećano klizanje sa povećanjem momenta kočenja dovodi do značajnih variranja u rastojanju između sadnica. Zato je za konstruktore sejalica i sadilica važan odnos kočionog momenta i klizanja. Odnosi između vuče, momenta i klizanja karakterišu ponašanje kočenog točka. Ovaj ogled je izveden da bi se odredilo klizanje pri različitim visinama poteznice (15, 20, 25, 30, 35 i 40 mm), različitim osovinskim opterećenjima (98.1, 147.15 i 196.2 N) i različitim obrtnim momentima. Razvijen je regresioni model koji uključuje klizanje (s), visinu poteznice (L) i obrtni moment (T). Osovinsko opterećenje nije imalo značajan uticaj na klizanje u ispitivanom opsegu. Regresioni model je imao oblik kvadratne polinominalne jednačine (R^2 = 0.82). Očekivana vrednost klizanja pri različitim visinama poteznice i kočionim momentima izračunavani su iz regresione jednačine i prikazani u tabeli. Ovo se može upotrebiti za određivanje visine poteznice kada su poznati potrebni obrtni moment i dozvoljeni nivo klizanja. Može se uočiti da klizanje raste sa opadanjem visine poteznice pri skoro svim vrednostima kočionog momenta.

Ključne reči: *vuča, obrtni moment, klizanje, osovinsko opterećenje, pogonski točak*

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