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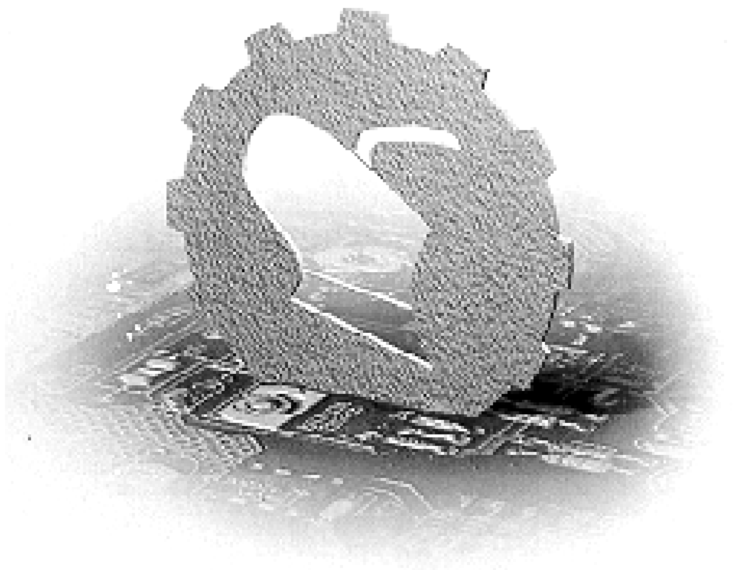

УНИВЕРЗИТЕТ У БЕОГРАДУ, ПОЉОПРИВРЕДНИ ФАКУЛТЕТ,
ИНСТИТУТ ЗА ПОЉОПРИВРЕДНУ ТЕХНИКУ
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# DEVELOPMENT AND EVALUATION OF MULTI TOOLBAR NO-TILL DRILL WITH RESIDUE HANDLING DEVICE UNDER VARIOUS PADDY RESIDUE CONDITIONS

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***Abstract*:** A multi-toolbar no-till drill has been designed and developed which could work satisfactorily in combine harvested paddy fields. Performance evaluation of the machine was conducted for under three different paddy residue conditions, i.e. chopped paddy residue conditions spread loose straw conditions and tillage condition (control). The multi-toolbar no-till drill was compered powered coulter double disc type drill. The maximum effective field capacity of 0.45 ha·h$^{-1}$ was found in Pantnagar no-till drill ($M_4$) followed by multi-toolbar no-till drill ($M_1$) as 0.39-0.42 ha·h$^{-1}$, multi-toolbar no-till drill with residue handling device ($M_2$) as 0.38 ha·h$^{-1}$ and -powered coulter double disc type drill ($M_3$) as 0.34-0.33 ha·h$^{-1}$. The maximum field efficiency of 73.5 % was found in machine ($M_4$) followed by 68.75 to 70.83 % for machine ($M_3$), 63.5 to 63.8 % for machine ($M_1$) and 60.2 to 61.4 % for machine ($M_2$). The maximum plant emergence of 161 plants·m$^{-2}$ was observed in case of treatment $T_7$. Highest yield of 5.8 t·ha$^{-1}$ was observed in treatment $T_3$ where machine $M_2$ (multi-toolbar no-till drill with residue handling device) un-chopped residue condition. Almost similar yield was observed for the treatment $T_1$, $T_3$ and $T_7$ (control) as the same did not differ significantly at 5 % level of significance.

***Keywords****: residue handling, no-till drill, sowing method, furrow opener, wheat sowing, field performance*

## INTRODUCTION

Rice-wheat cropping system is very common in India. These two crops together contribute more than 70 % of the total cereal production in the country from an area of

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about 25 Mha under wheat (Anonymous, 2013) and about 44 Mha under rice (Kumar *et al*. 2014).

The loose straw delivered behind the combine harvesters poses many management problems. Residue management is receiving a great deal of attention because of its diverse and positive effects on physical, chemical and biological properties of soil. No-till drills of various makes could be used successfully for direct seeding the crop but loose residue hinders the smooth operation of these drills. Disc openers cause less soil disturbance than hoe openers because they create a narrower furrow (Munir, *et al*., 2012). The limitations of disc openers are less draft requirement but large vertical force for penetration. In addition, even where penetration is adequate, "hairpinning" (forcing of uncut straw or chaff into the furrow) may result in seed "pop-up" after the disc drill passes, thereby reducing seed-to-soil contact. Poor seed-to- soil contact interferes with germination and seedling establishment and is often responsible for poor stands in chaff rows.

The drills equipped with hoe, chisel, winged chisel or inverted "T" type furrow openers, give more positive depth control. In heavy crop residue or when row spacing is narrow, inverted T-type furrow openers is prone to blockage between the two adjacent openers, causing operators irritation as well as reducing field capacity.

Hence, for proper residue management in direct drilling of wheat, the main operational problem of straw accumulation in combine-harvested paddy field is to be solved. Keeping the above aspect in view the straw multi-toolbar no-till drill was designed and developed and present work was undertaken with the objective to "development and evaluate the field performance in sowing of wheat crop by the new machine under different paddy residue conditions".

## MATERIAL AND METHODS

*Straw Handling Device and its Attachment.* It is a tractor mounted PTO operated machine with adjustable ground clearance residue collecting fingers. It is attached ahead of the no-till drill as an attachment. As the tractor moves forward, the loose straw is thrown over the already sown area and direct sowing operations could be performed simultaneously. A flat rubber belt of size 152 mm and thickness 7.2 mm has been used as the conveyor belt for the straw thrower. Drive and driven pulleys of 152 mm diameter and width 152 mm were selected and keyed to a shaft of 420 mm length and 25 mm diameter. V-belt sheave of 120 mm diameter was keyed to the shaft for transmitting power from main shaft drive pulley. Straw fingers of 170 mm length made of spring steel wires having 5 mm diameter were fitted on the flat belt at a spacing of 400 mm with each other. Power transmission shaft of 770 mm length made of mild steel (M S) rod of 35 mm diameter was used to transmit the power from tractor PTO to straw throw or assembly. Straw thrower assembly could be attached mounted with no-till drill by attaching it to ahead the front of multi tool bar no-till drill by clamps. Clamps are made of MS strips of dimensions 150 × 50 × 12 mm.

*Multi Toolbar No-Till Drill. Main frame:* Two angle irons of 50 × 5 mm size having 2092 mm length were welded together to form a square hollow section beam with a cross-section of 50 × 50 mm. In all, three beams of identical size with above mentioned specifications were fabricated. All the three beams were joined together in parallel position with another two side hollow square beams having cross-section of 40 × 40 mm to form a rectangular frame with overall length of 2092 mm and width 1830 mm respectively.

*Seed and fertilizer box:* The seed and fertilizer box of multi-toolbar no-till drill is made by using mild steel sheet. Both seed and fertilizer box is made of equal size and joint together in the centre along the length. The trapezoidal shaped seed and fertilizer boxes (top width 250 mm, bottom width 150 mm, depth 31 cm in centre and length of box 2500 mm) are made from 20 gauge M S sheet.

*Depth control device:* Depth control wheels are made from 80 mm wide and 6 mm thick M S flat with diameter 335 mm to support the equipment with in operation. It also provided a uniform depth of operation. Two such wheels have been provided to both sides of the frame. Depth of the wheel could be varied by holes in the arm and by adjusting the nut and bolts.

*Power transmission unit:* A ground wheel of 349 mm diameter with rim width 80 mm and thickness of 6 mm was fabricated from M.S. flat for power transmission. The wheel was provided with 4 spokes of M S flat (120 × 25 × 5 mm). 11 lug of spikes 100 × 50 × 5 mm size with tapered end were welded on the periphery. Two stage chain drive is provided from wheel to the main drive shafts and farther to fertilizer and seed metering units. In first stage, chain drive is provided from ground wheel to a counter shaft. In second stage drive was arranged from counter shaft to seed and fertilizer metering unit. The transmission ratio between ground wheel and seed and fertilizer metering unit is kept as 1:2. A floating arm is used to connect the ground wheel at rear right end of the main frame.

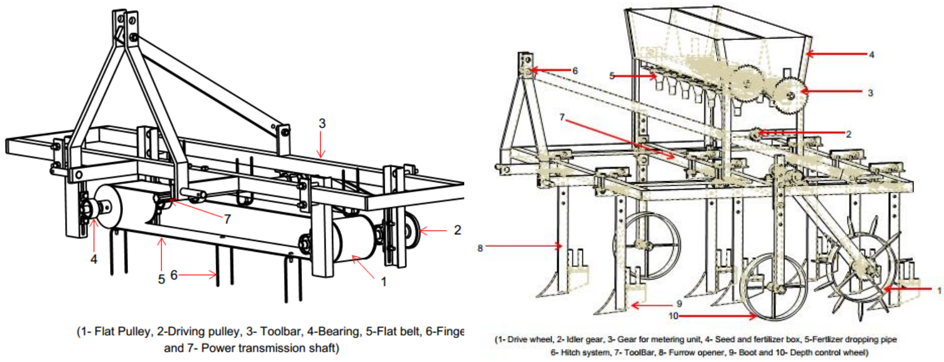


*Figure 1. Isometric view of prototype residue handling device and multi toolbar no-till drill*

*Seed and fertilizer metering unit:* The seed metering mechanism (flutted roller) is fitted under the bottom of seed box. Seven numbers of flutted rollers, having 12 numbers of flutes, with aluminium feed cups are fitted on a common shaft for metering the seed. Seed rate adjustment is obtained by sliding the flutted roller in or out into feed cups.

An adjustable orifice with agitator type fertilizer metering mechanism has been used, in the no-till drill, for metering of fertilizer. In this type of metering mechanism, fertilizer flow is regulated by changing the size of the opening provided on the movable (M S) flat at the bottom of the fertilizer box. A rubber agitator fixed above the opening in the fertilizer box helps in maintaining continuous flow of fertilizer. This mechanism was

adopted because of its ability to meter medium and small size fertilizer with fair accuracy, in design as well as its and simplicity with low cost.
Polyethylene tubes of 25 mm diameter and 2 mm thickness have been were used to convey seed from orifice to the furrow opener under gravity.

*Furrow opener:* Seven inverted-T type furrow openers are mounted to the frame of the drill with clamps. The overall height of the furrow opener is kept 720 mm which providing a clearance of 650 mm between ground and frame of the drill. The furrow opener is made from 8 mm thick high carbon bit welded to a mild steel plate. Furrow openers shank made of medium carbon steel flat with a 16×50 mm cross section. The rake angle is kept 28º in order to make a slit 3 to 5 cm in the soil. The relief angle of the blade is kept 8º. The furrow opener is welded to the shank in place of bolting it through nut and bolts.

*Field performance and evaluation.* Comparative field performance evaluation of the developed multi-toolbar no-till drill was carried out in different treatment at crop research center, G B Pant University of Agriculture and Technology, Pantnagar. Geographically, it is located at 29°N latitude and 79.29°E longitude and an altitude of 243.84 meter above mean sea level which is embodied with wet moisture regime and high water table conditions for most part of the year.

The soil of the experimental field is loam in texture, medium in organic carbon, medium in available phosphorus and high in available potassium. The soil pH values ranges between 7.2 and 7.3 which is slightly alkaline in nature. The soil organic carbon content varies from 0.62 to 0.68 %. The available phosphorus and potassium were observed as 37 and 180.5 kg/ha. The soil of the experimental field is silty clay loam with sand: silt: clay contents of 36.2:47.6:16.2 %. The average initial bulk density and moisture content were observed as 1.55 g/cc and 21.94 % (d.b) respectively, at the depth of 150 mm before conducting the experiment.

It was compared with other existing drill for wheat sowing and harvesting in experimental field on 8-Nov-2013 and 16-Aprail-2014 respectively. Trial was conducted to assess the machine and crop parameters including crop yield. Wheat variety (DWP-621-50) was sown in each experimental plot at recommended seed and fertilizer rate. The experiment was laid out in randomized block design with seven treatments and three replications each. The size of each plot was 28×4.5 m. The experiment was carried out with the following treatments:

$T_1$ - Un-chopped residue + multi-toolbar no-till drill
$T_2$ - Chopped residue+ multi-toolbar no-till drill
$T_3$ - Un-chopped residue + residue handling device + multi-toolbar no-till drill
$T_4$ - Chopped residue + residue handling device + multi-toolbar no-till drill
$T_5$ - Un-chopped residue+ Powered coulter double disc type drill
$T_6$ - Chopped residue + Powered coulter double disc type drill
$T_7$ - Control (conventional method of sowing)

Experiment was conducted to evaluate the machine performance, speed of operation, fuel consumption, draft, depth of sowing, field capacity, field efficiency, residue conveying efficiency, % and Residue flow percentage.

The crop parameters noted were germination count, tillering count, final plant stand, plant height, number of spikes, spike length, number of grains per spike, thousand grain weights and grain yield.

## RESULTS AND DISCUSSION

*Initial field condition.* The bulk density of the soil was observed as 1.55 g/cc in un-chopped and chopped residue field and 1.31 g/cc after tilled field. Soil moisture content was observed as 21.94 % (db) in both in residue un-chopped and chopped field. The moisture content of soil was observed less in tilled field (19.56 %) in compared to chopped and un-chopped un-tilled field, because soil moisture reduced slightly during tillage operation.

The average loose residue load and anchored stubble load in the un-chopped residue field was observed as 0.789 and 1.870 kg/m$^2$ at an observed moisture content of 32.56 and 69.03 % (wb), respectively. The average residue load in the chopped residue field was observed as 1.950 kg/m$^2$ at an observed moisture content of 43.2 % (wb). The average clod mean weight diameter, in tilled field, was observed as 15.45 mm.

*Field performance of no-till drill.* The seven field treatment combination was sowing by four type no-till seed drill. The treatment $T_1$ and $T_2$ was sowing by Multi-toolbar no-till drill ($M_1$), treatment $T_3$ and $T_4$ by Multi-toolbar no-till drill with attached residue handling device ($M_2$), treatment $T_5$ and $T_6$ by Powered coulter double disc type drill ($M_3$) and treatment $T_7$ by Pantnagar no-till drill ($M_4$). The forward speed was recorded 3.2, 3.0, 3.8 and 4.05 km/h in the no-till drill $M_1$, $M_2$, $M_3$ and $M_4$ respectively (Table-1). The maximum fuel consumption was recorded as 3.54 l/h in Powered coulter double disc type drill ($M_3$) fallowed by 3.47, 3.31 and 3.26 l/h in multi-toolbar no-till drill ($M_1$), multi-toolbar no-till drill with attached residue handling device ($M_2$) and Pantnagar no-till drill ($M_4$) respectively.

The maximum depth of sowing of 7.0 cm was measured in treatment $T_3$ followed by 6.83, 6.7, 6.5, 5.7, 4.9, and 4.7 cm in treatment $T_4$, $T_2$, $T_1$, $T_7$, $T_5$ and $T_6$ respectively. Depth of sowing was observed more in no-till condition because of more depth of the slit opened by the no-till drill. The lower seed placement depth occurred in case of powered coulter double disc type no-till drill due to large amount of residue condition. The maximum effective field capacities of 0.45 ha/h was found in no-till drill ($M_4$) followed by $M_1$ (0.39-0.42 ha/h), $M_2$ (0.38 ha/h) and $M_3$ (0.34-0.33 ha/h) (Table:1). The maximum field efficiency of 73.5 % was found in machine ($M_4$) followed by 68.75 to 70.83 % in machine ($M_3$), 63.5 to 63.8 % in machine ($M_1$) and 60.2 to 61.4 % in machine ($M_2$). Residue conveying efficiency was found as 81.6 and 22.1 % in $T_3$ and $T_4$ treatments respectively. The minimum residue flow percentage was found as 78.56 % in $T_1$ treatment followed by 97.6 % in $T_3$, which was sown in un-chopped field conduction. In treatment $T_2$, $T_4$, $T_5$ and $T_6$, the residue flow percentage was found as 100 %.

The field condition directly affect the performance of machine, the higher speed of operation and field efficiency were found in treatment $T_{7,}$ which may be due to the field condition of control treatment was ideal for sowing of wheat crop. The multi-tool bar no-till drill was operated in no-till field with standing stubble and loose straw condition, due to the lower performance of machine was found in compare to existing no-till drill. The amount of residue into the field is directly related machine performance all the tested conditions. Other parameters affecting crop residue cutting ability of a no-till disc opener such as disc diameter, downward pressure, sowing depth, straw water content, and forward speed, must be taken into consideration. The effects of tillage on residue cover depend on the speed and depth of tillage operation, type of implement, soil conditions, type and amount of residues, and the height of standing stubbles**.**

*Table 1. Field performance of different drills under various field conditions*

| *Sl. No.* | *Treatments* | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ |
|---|---|---|---|---|---|---|---|---|
| *1.* | *Speed of operation, km/h* | *3.2* | *3.2* | *3.0* | *3.0* | *3.8* | *3.8* | *4.05* |
| *2.* | *Fuel consumption, l/h* | *3.31* | *3.31* | *3.47* | *3.47* | *3.54* | *3.54* | *3.26* |
| *3.* | *Draft, N* | *3045* | *3044.5* | *3288.2* | *3282* | *-* | *-* | *4600* |
| *4.* | *Depth of sowing, cm* | *6.5* | *6.7* | *7.0* | *6.83* | *4.9* | *4.7* | *5.7* |
| *5.* | *Field capacity, ha/h* | *0.39* | *0.42* | *0.38* | *0.38* | *0.34* | *0.33* | *0.45* |
| *6.* | *Field efficiency, %* | *63.5* | *63.8* | *60.2* | *61.4* | *68.75* | *70.83* | *73.5* |
| *7.* | *Residue conveying efficiency %* | *-* | *-* | *81.6* | *22.1* | *-* | *-* | *-* |
| *8.* | *Residue flow, %* | *78.56* | *100* | *97.6* | *100* | *100* | *100* | *-* |

*Effect on crop parameter. Plant emergence and final plant stand:* The type of opener played a significant role in the speed of crop emergence (Table 2). The number of plants/m$^2$ (20 DAS) varied between 131.1 and 161.7. The maximum plant emergence of 161 plants/m$^2$ was observed in case of treatment $T_7$, followed by 151.3 plants/m$^2$ in $T_2$, 148.7 plants/m$^2$ in $T_4$, 140.7 plants/m$^2$ in $T_3$, 139.1 plants/m$^2$ in $T_1$ and $T_5$ and 131.7 plants/m$^2$ in $T_6$ respectively. The lower plant emergence occurred in treatment $T_6$ which may be due to minimum death of seed placement and slots were opened widely. By that fact the seeds were more exposed in the sun light. The highest plant emergence occurred in conventional sowing ($T_7$), which may be due to proper depth of seed placement and sore soil seed contact. In the presence of crop residue, the winged furrow opener created inverted T-shaped groove and the hoe-type furrow opener created U-shaped groove that resulted in greater number of seedling emergence, oxygen diffusion rates and earthworms activity than V-shaped groove created by the disk furrow opener. Saharawat et al. (2010) also reported about 15% higher effective tillers in Zero Tillage planter seeded wheat than Conventional Tillage Wheat.

*Number of effective tillers and final plant stand:* The effective tillering count was noted at 30, 60 and 90 DAS, and is shown in Table 2. The number of tillers/m$^2$ increased during the period between 30 and 60 DAS and then reduced in numbers for period between 60 and 90 DAS. The highest number of tillers/m$^2$ were observed for treatment $T_7$ (188.3 tillers/m$^2$) followed by $T_1$ (172 plants/m$^2$), $T_2$ (166 plants/m$^2$), $T_4$ (161.7 plants/m$^2$), $T_5$ (160.0 plants/m$^2$), $T_3$ (155 plants/m$^2$), and $T_6$ (145 plants/m$^2$), respectively at 30 DAS. The tiller population differed significantly ($P<0.05$) from one another among different treatments at 60 DAS. The highest number of tillers/m$^2$ were observed as 443 in treatment $T_7$ followed by 388.7 in $T_3$, 373 in $T_1$, 371 in $T_4$, 370 in $T_2$, 341.7 in $T_5$ and 326.7 in $T_6$, respectively. The tiller population at 90 DAS in different treatments is sown in table 2. It is clear from LSD value that at 90 DAS also, the tillers population differed significantly ($P<0.05$). The highest number of tillers/m$^2$ was observed as 394 in treatment $T_7$, followed by 339 in $T_1$, 337 in $T_3$, 322 in $T_2$, 310 in $T_4$, 309 in $T_5$ and 297 in $T_7$, respectively.

*Plant height:* The maximum plant height was found as 24.9 cm in treatment $T_3$ at 30 DAS, it is significantly higher in comparison to control. At 60 and 90 DAS the maximum plant height was observed in treatment $T_7$ which were at par with the plant height in treatments $T_1$, $T_2$, $T_3$, and $T_4$. Plant height in treatments $T_5$ and $T_6$ was found significantly lower in comparison to rest of the treatments where both the treatments differed non-significantly. Findings revealed that plant height was maximum recorded under conventional tillage. Similar results were also reported by LI Su *et al (*2006) and Singh *et al.* (2006). The possible reason of lower plant height under no-tillage with residue and standing stubble condition could be that crop under no-tillage condition received crop growth competition with standing stubble which might have reduced the plant height as compared to control condition.

*Table 2. Effect of treatments on plant emergence and tillers*

| *Treatment* | *Number of Plant emergence/m$^2$* | *Number of effective tillers/m$^2$* | | |
|---|---|---|---|---|
| | *20 DAS* | *30 DAS* | *60 DAS* | *90 DAS* |
| *T1* | *139.3* | *172.0* | *373.3* | *339* |
| *T2* | *151.3* | *166.7* | *370.0* | *322* |
| *T3* | *140.7* | *155.0* | *388.7* | *337* |
| *T4* | *148.7* | *161.7* | *371.7* | *310* |
| *T5* | *139.3* | *160.0* | *341.7* | *309* |
| *T6* | *131.7* | *145.0* | *326.7* | *297* |
| *T7* | *161.0* | *188.3* | *443.0* | *394* |
| *LSD 5%* | *16.7* | *19.7* | *27.8* | *18* |

*Table:3 Effect of treatments on crop growth parameters*

| *Treatments* | *Plant height, cm* | | | |
|---|---|---|---|---|
| | *30 DAS* | *60 DAS* | *90 DAS* | *At the time of harvesting* |
| *T1* | *24.3* | *42.1* | *72.1* | *90.4* |
| *T2* | *22.9* | *41.4* | *72.2* | *91.0* |
| *T3* | *24.9* | *40.0* | *70.5* | *91.3* |
| *T4* | *22.8* | *40.1* | *72.0* | *91.7* |
| *T5* | *19.4* | *38.2* | *66.9* | *84.0* |
| *T6* | *17.9* | *38.0* | *68.0* | *83.7* |
| *T7* | *18.3* | *42.5* | *76.9* | *96.0* |
| *LSD at 5%* | *3.4* | *NS* | *3.9* | *2.6* |

*NS-Non-significant*

*Yield and yield attributes. Number of spikes:* The difference in number of spikes/m$^2$ for different treatments was significant. The average number of spikes/m$^2$ was highest in treatment $T_7$ (385.7 spikes/m$^2$), was performed by followed by $T_3$ (311.0 spikes/m$^2$), $T_1$ (305.0 spikes/m$^2$), $T_2$ (294.3 spikes/m$^2$), $T_4$ (288.7 spikes/m$^2$), $T_5$ (281.0 spikes/m$^2$) and $T_6$ (275.7 spikes/m$^2$). The higher spikes count in case of treatment $T_7$ (conventional sowing) may be due to the better seed placement as indicated by tillage operation and also highest plant emergence with higher tillering count at different stages of crop growth. Lower spikes count in treatment $T_6$ may be due to less plant emergence.

*Spike length:* Spike length was significant difference in spike length obtained in different treatments. The highest spike length of 9.8 cm is observed in case of treatment $T_7$ followed by $T_5$ (9.4 cm), $T_1$ and $T_4$ (9.3 cm), $T_3$ (9.2 cm), $T_6$ (9.0 cm) and $T_2$ (8.9 cm), respectively.

*Number of grains per spike:* Wheat crop establishment method had non-significant effect on grain count per spike in all the treatments. The treatment $T_3$ gave highest grain count (60.7 grains/spike) followed by treatments $T_7$ (58 grains/spike), $T_1$ (57 grains/spike), $T_2$ (55.0 grains/spike) $T_4$ (54.7 grains/spike), $T_5$ (45.3 grains/spike) and treatments $T_6$ (45.0 grains/spike) where all the treatments yielded statistically at par. The observation on spike length under all the establishment method produced non-significant results, which differed at 5 % level of significance.

*Test (1000-grains) weight:* The test weight was more in $T_3$ (47.5 g) followed by $T_5$ (46.5 g), $T_7$ (46.0 g), $T_4$ (45.5 g), $T_2$ (44.5 g), and treatment $T_1$ and $T_7$ (43.5 g). The difference was observed statistically significant at 5 % level of significance. Maximum test weight was recorded under $T_3$ which was significantly higher than $T_7$, $T_1$, $T_2$, and $T_4$ and at par with $T_5$ and $T_6$.

*Table 4. Effect of various treatments on crop yield attributes*

| *Treatments* | *Number of spikes/ m$^2$* | *Spike length Cm* | *Number of grains/ spike* | *Test weight g* | *Grain yield t/ha* |
|---|---|---|---|---|---|
| *T1* | *305.0* | *9.3* | *57.3* | *43.5* | *5.5* |
| *T2* | *294.3* | *8.9* | *55.0* | *44.5* | *4.7* |
| *T3* | *311.0* | *9.2* | *60.7* | *47.5* | *5.8* |
| *T4* | *288.7* | *9.3* | *54.7* | *45.5* | *4.1* |
| *T5* | *281.0* | *9.4* | *45.3* | *46.5* | *3.8* |
| *T6* | *275.7* | *9.0* | *45.0* | *46.0* | *3.4* |
| *T7* | *385.7* | *9.8* | *58.0* | *43.5* | *5.6* |
| *LSD at 5%* | *21.8* | *NS* | *NS* | *2.4* | *0.6* |

*NS-Non-significant*

*Grain yield:* Highest yield of 5.8 t/ha was observed in treatment $T_3$, where un-chopped residue combined with residue handling unit and multi-toolbar no-till drill followed by $T_7$ (5.6 t/ha), $T_1$ (5.5 t/ha), $T_2$ (4.7 t/ha), $T_4$ (4.1 t/ha), $T_5$ (3.8 t/ha), and $T_6$ (3.3 t/ha), respectively. Crop yield in $T_3$ and $T_1$ treatment was recorded non-significantly to the control. Higher grain yield was produced under treatment, where un-chopped residue field condition prevailed. This may be due to better crop establishment throughout the crop season resulting in higher plant stand at the time of harvesting, higher number of spikes/m$^2$ and higher 1000-grains weight. The better crop establishment in these treatments may also be due to decomposition of crop residue slowly as it maintained moisture level on the surface throughout the crop season. Spike length and plant height were high in case of using no-till drill with the residue manager, which increased the grain yield by 12.4 % more than using no-till drill without this attachment (Hegazy and Dhaliwal, 2011). Kumar *et al.* (2013) reported the grain yield in Zero Tillage Wheat was 6% and 10% higher than Rotovator Tillage Wheat and Conventional Tillage Wheat, whereas, lowest yield was observed in Reside Bed Planting Wheat. The grain yield of winter wheat was higher 11.65% in technologies which included mulch tillage system than conventional technologies (Kovacevic *et al.*, 2005).

## CONCLUSION

The maximum effective field capacity of 0.45 ha/h was found in Pantnagar no-till drill ($M_4$) followed by multi-toolbar no-till drill ($M_1$) as 0.39-0.42 ha/h, multi-toolbar no-till drill with residue handling device ($M_2$) as 0.38 ha/h and -powered coulter double disc type drill ($M_3$) as 0.34-0.33 ha/h. The maximum field efficiency of 73.5 % was found in machine ($M_4$) followed by 68.75 to 70.83 % for machine ($M_3$), 63.5 to 63.8 % for machine ($M_1$) and 60.2 to 61.4 % for machine ($M_2$).

The maximum plant emergence of 161 plants/m$^2$ was observed in case of treatment $T_7$ followed by 151.3 in $T_{2,}$ 148.7 in $T_4$, 140.7 in $T_{3,}$139.1 in $T_1$ and $T_5$ and 131.7 plants/m$^2$ in $T_6$.

Highest yield of 5.8 t/ha was observed in treatment $T_3$ where machine $M_2$ (multi-toolbar no-till drill with residue handling device) un-chopped residue condition. This was followed by $T_7$ (5.6 t/ha), $T_1$ (5.5 t/ha), $T_2$ (4.7 t/ha), $T_4$ (4.1 t/ha), $T_5$ (3.8 t/ha) and $T_6$ (3.3 t/ha). Almost similar yield was observed for the treatment $T_1$, $T_3$ and $T_7$ (control) as the same did not differ significantly at 5 % level of significance.

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# RAZVOJ I OCENA VIŠENAMENSKE SEJALICE ZA DIREKTNU SETVU SA UREĐAJEM ZA OBRADU OSTATAKA U RAZLIČITIM USLOVIMA

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***Sažetak*:** Višenamenska direktna sejalica konstruisana je i razvijena za rad na parcelama posle kombajniranja pirinča. Ocena performansi mašine je izvedena u tri različita stanja ostataka. Maksimalni efektivni poljski kapacitet od 0.45 $ha \cdot h^{-1}$ kod Pantnagar sejalice ($M_4$), zatim kod sejalice ($M_1$) 0.39-0.42 $ha \cdot h^{-1}$, sejalice sa uređajem za obradu ostataka ($M_2$) 0.38 $ha \cdot h^{-1}$ i sejalice sa reznim diskovima ($M_3$) 0.34-0.33 $ha \cdot h^{-1}$. Maksimalna efikasnost od 73.5 % je izmerena kod mašine ($M_4$), zatim 68.75 do 70.83 % kod mašine ($M_3$), 63.5 do 63.8 % kod mašine ($M_1$) i 60.2 do 61.4 % kod mašine ($M_2$). Najveći prinos od 5.8 $t \cdot ha^{-1}$ je izmeren u tretmanu $T_{3.}$ Sličan prinos je bio kod tretmana $T_1$, $T_3$ i $T_7$ (kontrola).

***Ključne reči:*** *obrada ostataka, direktna setva, metod setve, otvarač brazed, setva žita, osobine parcele*

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# DESIGN AND DEVELOPMENT OF A YIELD MONITOR FOR GRAIN COMBINE HARVESTER

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***Abstract:*** Yield monitor is an important development in precision farming that allows the farmers to assess the yield variability within the field during crop harvesting. In advanced countries, developed yield monitors used for high hp combines cannot be applied on small indigenous combines due to design constraint and high cost. So, to spread the use of yield monitoring combines in India, it was necessary to develop an indigenous yield monitor for indigenous combines. For development of an indigenous yield monitor, components such as auxiliary tank, load cell, inductive sensor and display unit with micro-controller were identified. Indigenous yield monitor was developed by assembling designed/selected components on local manufactured combine. Yield monitor was also calibrated and evaluated in the field. The average value of measured yield was 3931.1 $kg \cdot ha^{-1}$ with a standard deviation of 2020.8 $kg \cdot ha^{-1}$ having coefficient of variation 51% which indicated that yield variability existed within the small and marginal field.

***Keywords:*** *precision agriculture, combine harvester, yield monitor, load cell calibration, yield variability*

## INTRODUCTION

Paddy-wheat is one of the most extensively adopted cropping patterns of Northern India. The total production of rice and wheat in India was 106.54 and 95.91 million tons in the year 2013-14. Similarly, in Punjab total production of rice and wheat was 11.27 and 10.17 million tons, respectively in the same year [1]. In Punjab, during last sixty

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years, agricultural production has increased manifold and this increase in production was because of advancement in technologies and innovations, use of fertilizers, pesticides, insecticides, high yielding, semi-dwarf and short duration varieties. Although, these technologies and innovations have improved the socio-economic conditions of the farmers but this has been done at a cost of environmental degradation [2]. The rice-wheat rotation in Punjab is very much resource demanding and has led to an agrarian crisis in Punjab in terms of depleting aquifers, reduced soil health, over exploitation of natural resources, unabated application of pesticides, loss of soil fertility and incorporation of non-biodegradable agricultural chemicals in soil and water. To increase the production and to protect the soil & environment from ill effects of chemicals, there is a need to adopt new farming techniques and technologies which help to protect our natural resources by using these resources optimally. Hence, precision farming is that technique which helps to achieve these goals. There are three basic steps i.e. assessing variability, managing variability and evaluation in precision farming. To assess the variability within a field or to get the first step of precision farming, yield monitoring devices are needed to develop.

A yield monitor is a recent development in precision farming and agricultural machinery that allows farmers to assess the yield variability in the field during harvesting of crop [3]. A yield monitor used in conjunction with a Global Positioning System (GPS) receiver records yield and location during harvest and give user an accurate assessment of how yields vary within a field. Although in advanced countries, high hp combines for large farms are available with yield monitors fitted as standard equipment or installed separately. An impact type flow meter was developed which measured grain forces on a curved circular tube using a load cell, near the top of a clean grain elevator [4]. An impact-type yield sensor with a curved plate was developed and tested in the lab; an error of 1 to 2% was noticed. However, the maximum error in the field was up to 3.5% [5].

An intelligent yield monitor for grain combine harvester was developed for harvesting the wheat crop. Field tests showed a linear relationship between actual yield and the output of the yield monitor. The error between measurement and prediction was less than 3%. It is concluded that the developed intelligent yield monitor is practical [6]. A modified version of optical sensor was designed to be specific to peanut mass-flow measurement. Test results showed that the output of the peanut mass-flow sensor was very strongly correlated with the harvested load weight, and the system's performance was stable and reliable during the tests. [7]. A batch type yield monitor was developed which was having a load cell of capacity 700 kg with drum size 125x85x80 cm for grain combines, used to measure the spatial variation of grains for use as single unit or by putting directly in trailer. combine mounted batch type yield monitor was also developed by fitting an auxiliary tank of size 145×100×85 cm in the main tank and load cell at the bottom of the auxiliary tank. Yield variability of three different locations having C.V. of 5.46%, 27.56% and 35.34% were observed during the evaluation of batch type yield monitor [8].

These developed yield monitors are difficult to install on indigenous combines directly, because the sensors and systems usually design for those high hp combines and are very costly. Consequently, there was an essential need to develop an indigenous yield monitor by keeping various things in mind i.e. small combine, low cost and easy working & installation. Although, farmer could understand the reasons of yield variations through routine farm work, a combine harvester installed with indigenous yield monitor was expected to play an important role in establishing site specific crop management and spreading related technology to farmers. In this view, the present study was taken with the aim of design and development of an indigenous yield monitor for grain combine harvester.

## MATERIAL AND METHODS

This chapter deals with the methods and material applied for the design and development of an indigenous yield monitor for grain combine harvester.

*Design of Indigenous Yield Monitor.* Design of indigenous yield monitor includes (1) Conceptual design of yield monitor (2) Design of auxiliary tank (3) Selection of load cell, micro-controller 8051, inductive/speed sensor and display unit

*Conceptual Design of Indigenous Yield Monitor.* Conceptual design of indigenous yield monitor was about the theoretical planning of how this yield monitor could be developed physically. Yield monitor worked on the principle that the change in voltage of Wheatstone bridge circuit in load cell will be correlated with the geo-referencing points of the small fields and stored in the data logger to sense the yield of sites falling in the combine tank. Different types of components such as auxiliary tank, single point parallel type load cell, micro-controller with display unit and speed sensor were needed to design/select for the development of an indigenous yield monitor. These components were designed and selected due to their compatibility and operation in the yield monitor. Parallel beam type load cell was selected because of its easy installation at the bottom of the auxiliary tank. In this load cell design tension and/or compression loading is possible, provides easy installation and flexible application. For the data acquisition, a micro-controller 8051 with data presentation element was selected for the study, due to its accuracy, easy installation and wider applicability. Inductive sensor is also known as metal detective sensor as used to detect the metallic object without physical contact. A 3-wire inductive proximity sensor was selected for present study because of its accuracy, compatibility and easier installation. Fig. 1 shows the conceptual design diagram of combine harvester installed with different components of indigenous yield monitor.

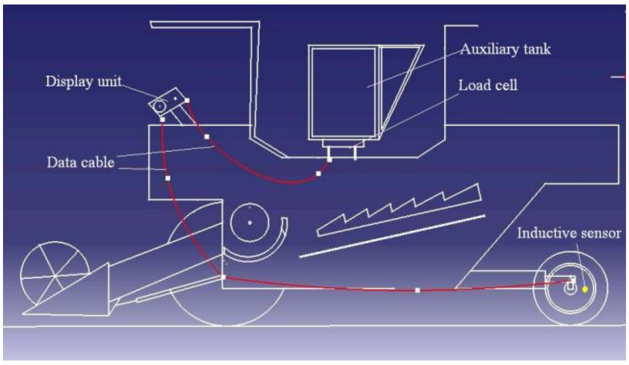


*Figure 1. Design diagram of combine harvester installed with different components of indigenous yield monitor*

*Design of Auxiliary Tank.* Auxiliary tank was an additional tank to collect the harvested grains and designed keeping in view that it should be fitted within the main tank of combine and there must have the provision and space to open auxiliary tank. It was made of steel sheet of 3 mm thickness and having a size of 1450 mm x 1000 mm x 850 mm. The angle iron of size 6 mm x 36 mm was used to make the frame of tank. The capacity of tank was about 200 kg for paddy grains.

*Selection of Load Cell, Inductive/Speed Sensor, Micro-controller and Display Unit.* Single point parallel load cell, having capacity of 700 kg, was selected due to its compatibility with the present monitoring system. In this load cell design, tension and/or compression loading were possible, provided easy installation and flexible application. A 3-wire inductive proximity sensor, a micro-controller 8051 for data acquisition and liquid cooled display unit for data presentation were selected for the indigenous yield monitor due to their accuracy, compatibility and easy installation.

*Development of Indigenous Yield Monitor*. Development of indigenous yield monitor includes mounting and assembling of yield monitor's components at combine harvester, working of yield monitor and software development.

*Mounting of Yield Monitor's Components at Combine Harvester*. Auxiliary tank was placed on the load cell bed within the main tank of combine harvester. Load cell was mounted under the auxiliary tank in between the designed load cell bed and platform. Micro-controller 8051 was used to store and process the data of load cell & inductive sensor and converted that data into readable form. Micro-controller was a small component and fitted inside the display unit which was placed at front of driver's cabin. The inductive/speed sensor was mounted on the rear axle to count the wheel revolution. It was mounted at rear wheels as these wheels have minimum slip in the field being the towed wheel.

*Assembling and Working of Indigenous Yield Monitor's Component*. After mounting the components of yield monitor on combine harvester, next step was to assemble these components with each others for accurate operation. Load cell, placed under the auxiliary tank was connected with Micro-controller's input pin 1. Inductive/speed sensor was fitted at the rear axle of combine and its signal wire was connected with Micro-controller's input pin 2. Micro-controller, installed inside of display unit was further connected with LCD of display unit, placed in front of operator's seat to present the output results. Fig. 2 shows the assembly of different components of indigenous yield monitor.

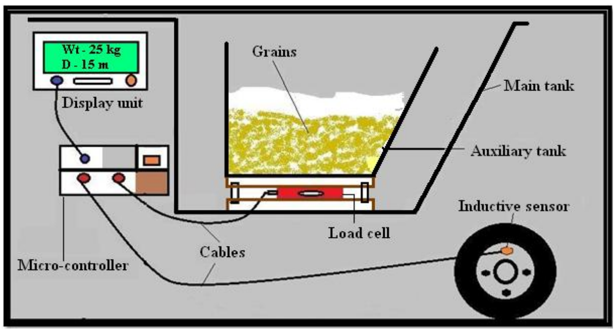


*Figure 2. Assembly of different components of indigenous yield monitor*

Harvested/processed grains coming through the elevator fall in the auxiliary tank and impact on load cell, fitted at the bottom of auxiliary tank. Load cell sent an analogue signal to signal condition element. Similarly speed/inductive sensor sent the signal to the conditioning element. In this element, analogue signal was converted into digital form and impurities of signal were removed. The digital data sent to the micro-controller for processing the data. Micro-controller stored and converted the data into understandable form. Display unit was the data presentation element which showed yield data in kilogram and distance in meter. Fig. 3 shows the block diagram of working operation of yield monitor.

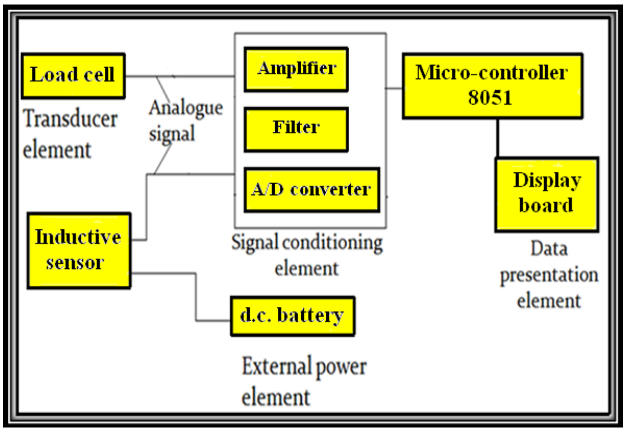


*Figure 3. Block diagram of working of indigenous yield monitor*

*Software Development.* Software in assembly language was developed to process the load cell and inductive sensor's data. The load cell calibrated data and inductive sensor pulse was fed to software for calculating the cumulative yield and travelled distance. The yield data in kilogram (kg) and traveled distance in meter (m) was displayed as output data by display unit/data presentation element.

*Calibration of Load Cell.* Load cell was calibrated by putting different loads in the auxiliary tank fitted with load cell placed under the auxiliary tank. Load cell connected with the micro-controller presented the 24 bits Hax value against the load (kg). The Hax value was converted into constant readable value with the help of available hexadecimal into decimal converter software. These constants values were converted into load (kg) with the help of calibration element. A straight line equation ($Y = 345.0x + 16146$) having $R^2 = 0.99$ was used to calculate the different values of load cell against different loads (kg). Tab. 1 show the calibration chart between load cell values and load/weight applied on load cell and R1, R2 and R3 represents the replications at different operating speed of combine harvester.

*Calibration and Accuracy of Inductive/Speed Sensor.* To test the sensing accuracy of speed sensor, a field was selected and a particular distance was measured with the help of measuring tape. Combine was run on field and sensor counted the wheel revolution. With the help of micro-controller, travelling distance of combine was calculated. After three replications, it was found that the measured distance and calculated distance was almost equal. Tab. 2 shows the accuracy of inductive sensor, where measured distance indicates the distance measured by measuring tape and calculated distance represents the distance calculated by micro-controller.

*Table 1. Calibration chart between load cell values and load/weight applied on load cell*

| Sr. No | Load (kg) | Load cell value | | | |
|---|---|---|---|---|---|
| | | R1 | R2 | R3 | Average |
| 1 | 0 | 161319 | 161327 | 161329 | 161325 |
| 2 | 30 | 171510 | 171515 | 171475 | 171500 |
| 3 | 60 | 183009 | 183013 | 182978 | 183000 |
| 4 | 95 | 194107 | 194112 | 194081 | 194100 |
| 5 | 130 | 206129 | 206137 | 206139 | 206135 |

*Table 2. Accuracy of inductive sensor*

| Sr. No | Measured distance (m) | Calculated distance (m) | Error (%) |
|---|---|---|---|
| 1 | 50 | 48.75 | 2.5 |
| 2 | 50 | 50.75 | -1.5 |
| 3 | 50 | 49.0 | 2.0 |

*Field Evaluation of Indigenous Yield Monitor*. Paddy crop was selected for field evaluation of indigenous yield monitor. Cumulative yield was measured and yield data was stored by the yield monitor after harvesting the crop at distance equal to circumference of rear wheel i.e. 2.5 meter of combine harvester. The variable yield data calculated from the measured cumulative yield data in each grid size of 10 $m^2$.

## RESULTS AND DISCUSSION

The yield monitor was evaluated for paddy crop of variety PR 118 to measure the yield variability with in the field.

*Yield Variability Measurement with Indigenous Yield Monitor.* Three strips of paddy crop were harvested at 3.0 km/h forward speed of combine harvester installed with indigenous yield monitor and yield variability data in each harvested grid of 10 $m^2$ area is shown in Fig. 4. In first strip the maximum and minimum yield was 9.09 kg and 1.21 kg in 15$^{th}$ and 14$^{th}$ grid of size 10 $m^2$ respectively. The moisture content of grains was varying from 15.6 to 15.9% on dry basis during the harvesting of selected crop area. In second strip the maximum and minimum yield was 7.09 and 1.7 kg in 13$^{th}$ and 2$^{nd}$ grid of size 10 $m^2$ respectively. Similarly, in third strip, the maximum and minimum yield was 7.46 and 0 .65 kg in 15$^{th}$ and 4$^{th}$ grid of size 10 $m^2$ respectively.

Yield variability maps of harvested strips at forward speed of 3.0 km/h are shown in Fig. 5. In first strip, the minimum yield i.e. below 2500 kg/ha was in the maximum area i.e. 37.5% followed by the yield having range 3750-5000 kg/ha in the area of 31.25%. The maximum yield i.e. more than 6250 kg/ha was in only 12.5% area. In second strip, the yield in the range 2500-3750 kg/ha was occupied the maximum area i.e. 37.5% followed by the yield range 5000-6250 kg/ha in the area of 18.75%. The maximum yield i.e. more than 6250 kg/ha was in only 12.5% area. In third strip, the minimum yield i.e. below 2500 kg/ha was in the maximum area i.e. 37.5% followed by the yield range 3750-5000 kg/ha in the area of 25%. The maximum yield i.e. more than 6250 kg/ha was in only 6.25% area.

The mean, standard deviation and coefficient of variation of yield data at forward speed of 3.0 km/h is given in Table 3. The average value of measured yield data in three harvested strips was 3931.1 kg/ha with a standard deviation of 2020.8 kg/ha having coefficient of variation 51%, which indicated that yield variability existed within the small and marginal field.

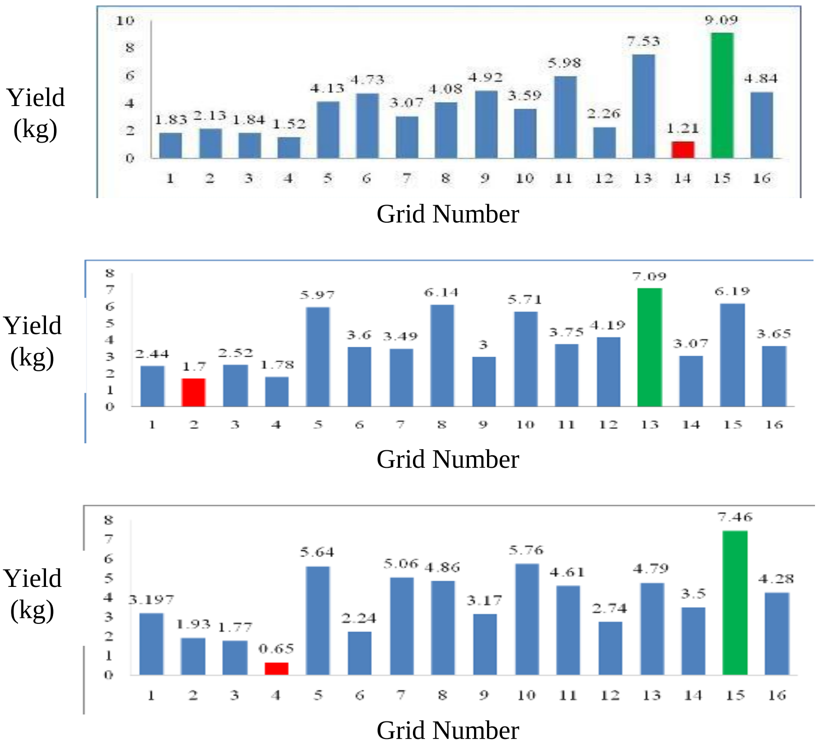


*Figure 4. Yield variability v/s Grid Numbers*

*Table 3. Mean, standard deviation (S.D.) and coefficient of variation (C.V.) at forward speed of 3.0 km/h*

| *Attributes* | *Forward speed (2 km/hr)* | | | |
|---|---|---|---|---|
| | *Strip 1 (R1)* | *Strip 2 (R2)* | *Strip 3 (R3)* | *Avg.* |
| *Mean (kg/ha)* | *3921.8* | *4018.1* | *3853.5* | *3931.1* |
| *Standard deviation (S.D)* | *2238.5* | *2051.9* | *1772.1* | *2020.8* |
| *Coefficient of variation (C.V) %* | *57* | *51* | *45* | *51* |

*Cost Analysis of Yield Monitor*. The major components of yield monitoring system were load cell, auxiliary tank and data acquisition system includes micro-controller, proximity sensor and display unit. The total cost of yield monitoring system comprising of load cell, auxiliary tank and data acquisition system was approximately Rs. 60000. Fixed cost of yield monitor includes depreciation, interest etc. and operating cost comprised of repair and maintenance of the system. Depreciation cost is calculated based upon the purchase price of the system. The interest rate for calculating the interest cost was assumed to be 10% and repair and maintenance cost was 5% of the purchase price. Total operational time for harvesting by combine harvester for rice, wheat and maize was assumed to be 150 days and field capacity of combine harvester was 0.75 hectare/hour. Hence, Total operational cost of yield monitor was calculated Rs. 12.5/hr or Rs, 16.50/ha.

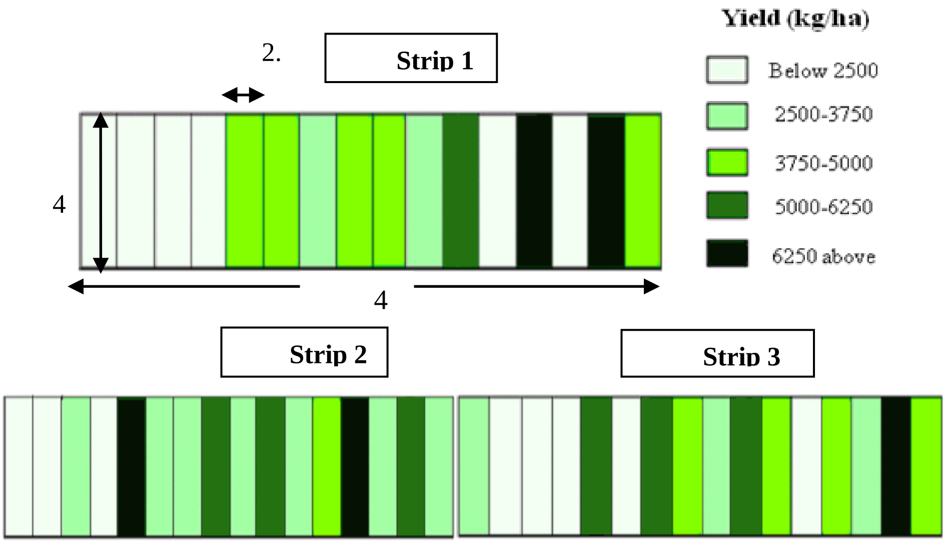


*Figure 5. Yield variability maps of harvested strips*

## CONCLUSIONS

The conceptual design of indigenous yield monitor was that when grains fell from combine elevator to auxiliary tank fitted in the main tank of combine, were measured by load cell fitted at the bottom of the tank. Single point parallel type load cell for yield measurement and inductive proximity sensor for distance measurement were selected for development of indigenous yield monitor due to their accuracy and compatibility. Micro-controller 8051 with display unit was selected to process the yield monitor's data. Indigenous yield monitor was developed by mounting and connecting these selected on locally manufactured combine harvester. Calibration of load cell indicated linearity between the loads (kg) and load cell values. The average value of measured yield was 3931.1 kg/ha with a standard deviation of 2020.8 kg/ha having coefficient of variation 51%, which indicated that yield variability existed within the paddy field.

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## KONSTRUKCIJA I RAZVOJ UREĐAJA ZA MERENJE PRINOSA NA ŽITNOM KOMBAJNU


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***Sažetak:*** Uređaj za merenje prinosa daje značajan doprinos razvoju precizne poljoprivrede tako što farmerima omogućuje merenje promenljivosti prinosa tokom žetve. U naprednim zemljama razvijeni uređaji ne mogu da se primene na malim kombajnima domaće proizvodnje zbog visoke cene i razlika u konstrukciji. Zato postoji potreba da se proširi upotreba monitora prinosa na domaćim kombajnima u Indiji, tako šro će se razviti domaći uređaj. Za razvoj ovog uređaja određene su domaće komponente: pomoćni rezervoar, ćelija tereta, indukcioni senszor i ekran sa mikro-kontrolerom. Uređaj od ovih komponenti je postavljen na domaći kombajn, kalibrisan i ocenjen u poljsim uslovima. Srednja vrednost izmerenog prinosa iznosila je 3931.1 $kg \cdot ha^{-1}$, sa standardnom devijacijom od 2020.8 $kg \cdot ha^{-1}$ i koeficijentom varijacije od

51%, što pokazuje da je promenljivost prinosa postojala u malom i zanemarljivom interval.

***Ključne reči:*** *precizna poljoprivreda, kombajn, merač prinosa, kalibracija ćelije tereta, promenljivost prinosa*

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# EFFECT OF TREATED WASTE WATER FROM FOOD PROCESSING INDUSTRIES IN TOMATO PRODUCTION THROUGH AUTOMATED DRIP IRRIGATION

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***Abstract:*** The Water is the necessary source for all forms of life. The existing trial was accompanied in Jain Irrigation System Ltd. Jalgaon (India), to check the feasibility of treated waste water from food processing industry in agriculture. The experiment was laid out in split plot design for tomato crop (*Lycopersican esculentum*) with two treatments viz., treated fruit waste water (M1), treated and bore well fresh water (M2). Two emitter were selected viz., Model B2.0 (Non pressure compensating – S2) and Model C2.0 (Pressure compensating and compensating non leakage – S1). The different observations on each treatment were taken such as uniformity coefficient, plant height, yield, protein content and lycopene, fiber, carbohydrates content. The results showed that the highest uniformity coefficient (97.9 %) M1 (01 DAS), plant height (69.82 cm) M1, yield (35.42 $t \cdot ha^{-1}$), protein (0.92 %) M1 and lycopen (4.28%) M2. In conclusion, treated fruit waste water can be used as an unconventional source of irrigation after fresh water source, as it has positive effect on crop growth, yield and quality parameters, also less maintenance while operating automated drip system as compared with treated fruit waste water.

***Key words****: waste water, uniformity coefficient, treated fruit waste water, bore bell fresh water, tomato*

## INTRODUCTION

Paper Waste water management in India has become an extremely important area of focus due to increasing health awareness and population pressure. Despite the wastewater sector witnessing major growth in the last decade due to increasing

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government support and private participation, the scale of the problem remains enormous. For instance, it is estimated that less than 20% of domestic and 60% of industrial wastewater is treated. Metros and large cities (more than 100,000 inhabitants) are treating only about 29.2% of their wastewater; smaller cities treat only 3.7% of their wastewater. (Anoon)

Agricultural use of water accounts for nearly 70 per cent of the water used throughout the world, and the majority of this water is used for irrigation. The sources of irrigation water are limited and demand for agricultural products is increasing. Inadequate access to water is one of the biggest problems faced the world. India is one such nation where demand of water has continuously overlapped its supply. The total water demand in the country in 2003 was close to 465 BCM which has been increased to 634 BCM in 2013 (www.snpinfrasol.com, 2014).The waste water from industries varies greatly in both flow and pollutional strength. Industrial wastewater may contain suspended, colloidal and dissolved (mineral and organic) solids. These wastes may contain inert, organic or toxic materials and possibly pathogenic bacteria. It is necessary to pre-treat the wastes water prior to release to the agriculture or municipal system. Jain Irrigation has food processing facilities for dehydration of onion, vegetables and production of fruit purees, concentrates and pulp. The annual average availability of treated waste water generated from fruit processing is 200000 cubic meters and from onion dehydration plant is about 150000 cubic meters (Anonymous, 2012). Tomato (Lycopersicon esculentum ) fruit, often described as a vegetable fruit is a true berry, a type of fleshy fruit characterized by its soft pulp, thin skin and many seeds. On a worldwide scale, tomato continues to increase in importance for consumption as a fresh crop, as a major constituent in many prepared foods and also as materials for research into the fundamental principles of growth and development in plantation. Economically, tomato tops the list in value among edible vegetables. Tomato fruits contain various minerals and vitamins (Decuypere, 2006). It is grown in 0.458 M ha area with 7.277 M mt production and 15.9 mt/ha productivity. The major tomato producing states are Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Maharashtra, Madhya Pradesh and West Bengal. In West Bengal, tomato is grown over an area of 43,600 ha with the production 0.588 M mt and productivity of 13.6 mt/ha. Tomato is rich source of vitamins A, C, potassium, minerals and fibers. . Tomatoes are used in the preparation of soup, salad, pickles, ketchup, puree, and sauces also consumed as a vegetable in many other ways. (Anon, 2011). However, major tomato cultivation area is spread in rain fed condition contributing around 80-82 per cent of annual production in *kharif*, whereas left over production come from *Rabi* and summer season under irrigated conditions. India is a second largest country to produce the tomato in the world. The tomato production in India 17,500,000 MT (FAOSTAT 2012). The world dedicated 4.8 million hectares in 2012 for tomato cultivation and the total production was about 161.8 million tonnes. The average world farm yield for tomato was 33.6 tonnes per hectare, in 2012.

## MATERIAL AND METHODS

Field experiment was conducted during 30$^{th}$ January 2015 to 30$^{th}$ May 2015 in Rabi season. The experiment was located at Jain irrigation Systems Ltd. Jalgaon, India. The climate is semi-arid and the average annual rainfall is 690 mm. The maximum and minimum temperature and ET during the cropping period was 33 °C and 12 mm day -1 and the minimum was 9.5 °C and 3.8 mm day-1 respectively. Soil texture of the experimental conducted site is sandy clay-loam. The total experimental area was about 1500 $m^2$ in the vicinity of food processing plant. The experiment was laid out in split plot design with 2 main treatments, 2 sub treatments with 5 replications are presented in the fig1. The raised beds of 1.2 m x 10 m were prepared for transplantation of tomato plant by maintaining plant and row spacing (30 cm x 40 cm). There were five replications for each treatment; Net plot size-9.2m x 8m and net plot area having about 720 $m^2$. Variety- Synzenta-1389 (Hybrid Tomato) was used for transplanting. The irrigation system consists of automatic irrigation controller, EC and PH sensor, Temperature sensor, Soil moisture sensor, Weather station, 5000 litre storage tank, 2.5 hp pump, 63 mm water meter, 25 $m^3$/hr. sand and disc filter, 40 mm control valves, 40 mm main line, 32 mm sub main lines, 16 inline laterals and other necessary details of treatment and sub treatments are explained below and depicted in plate1;

1. Main treatments (irrigation sources)
M1 - Treated fruit waste water (TFWW)
M2 - Bore well fresh water (BWFW)
2. Sub treatment (emitter types – discharge 2 lph, emitter spacing 30 cm)
S1 - Pressure compensating, compensating non leakage emitter (Model C2.0)
S2 - Non pressure compensating emitter (Model B2.0)

*Figure 1. Automated drip system and experimental tomato crop layout*

*Determination of peak water requirement.* Amount of irrigation water applied to drip treatments were based on daily pan evaporation readings. The water requirement of the crop was calculated based on the following equation mentioned in Jain Irrigation Systems Manual (Anonymous, 2008).

$$Q = A \times B \times C \times D \quad (1)$$

Where
$Q$ [lpd] Quantity of water required,
$A$ [$m^2$] Gross area per plant,
$B$ [-] Amount of area covered with foliage,
$C$ [-] Crop Coefficient.

$$D = K_p \times E_{pan} \quad (2)$$

Where
$K_p$ [-] Pan Coefficient

$E_{pan}$ [mm] Evaporation from Class A open pan Evaporimeter.

*Determination of uniformity coefficient (UC).* To determine the uniformity coefficient in drip irrigation the depth of water in the formula was replaced by discharge rate of drip and the discharge of emitter was measured by volumetric method for three minutes. The uniformity coefficient was calculated using equation:

$$UC=100\ [1- D/M] \tag{1}$$

Where
*UC* [%] Uniformity coefficient,
*D* [lph] Average absolute deviation from the mean discharge rate,
*M* [lph] Mean discharge rate.

Periodically observations on each treatment were taken for uniformity coefficient, plant height, yield, protein and fat content.

## RESULTS AND DISCUSSION

*Water analysis.* Treated waste water analysis revealed that all studied parameters were within permissible limit as declared by Maharashtra Pollution Control Board. Water analysis result should that the treated waste water from both fruit as well as onion processing industries was adding macro and micro nutrient in the water. Average value of waste water analysis is given in Table 1.

*Table1. Quality of treated waste water and fresh water used for experiment*

| *Parameter* | *Units* | *MPCB Norms* | *Different water treatment* | |
|---|---|---|---|---|
| | | | *TFWW* | *BWFW* |
| *TDS* | *Ppm* | *2100* | *810.67* | *788.30* |
| *pH* | | *6.5-9.0* | *7.27* | *6.73* |
| *BOD* | *Ppm* | *30* | *8.83* | *0.56* |
| *COD* | *Ppm* | *250* | *78.03* | *0.93* |
| *CI* | *Ppm* | *600* | *141.67* | *0.00* |
| *S* | *Ppm* | *1000* | *47.67* | *0.00* |
| *EC* | *ds/m* | *-* | *1.22* | *1.10* |
| *N* | *Ppm* | *-* | *2.23* | *0.48* |
| *P* | *Ppm* | *-* | *0.65* | *1.48* |
| *K* | *Ppm* | *-* | *44.23* | *50.94* |
| *Na* | *Ppm* | *-* | *175.67* | *23.36* |
| *Ca* | *Ppm* | *-* | *88.00* | *95.65* |
| *Mg* | *Ppm* | *-* | *53.67* | *34.35* |

*Soil analysis.* Soil samples were collected before sowing; the soil analysis results indicated that soil had clay loam texture with low bulk density and moderate field capacity. All the nutrients viz., major N, P, K, secondary Ca, Mg and S and micro nutrient Fe, Cu, Mn and Zn are comparatively higher in surface 10 cm soil with the exception of K which is higher in lower depths (Table 2).

*Table 2. Soil characteristics of the experimental plot before treatment*

| ***Parameters*** | ***Range*** | ***Soil Sampling*** |
|---|---|---|
| *N (kg/ha)* | *280 – 560* | *163.07* |
| *P (kg/ha)* | *23 – 56* | *2.23* |
| *K (kg/ha)* | *130 – 336* | *126.79* |
| *Ca (%)* | *0.05 -0.41* | *0.12* |
| *Mg (%)* | *0.01 – 0.05* | *0.08* |
| *Fe (ppm)* | *5 – 10* | *4.77* |
| *Mn (ppm)* | *5 – 10* | *3.52* |
| *Zn (ppm)* | *0.5 – 1.0* | *0.37* |
| *Cu (ppm)* | *0.2 – 0.4* | *2.41* |
| *S (ppm)* | *10 – 20* | *7.06* |
| *Sand (%)* | *-* | *34.48* |
| *Silt (%)* | *-* | *33.32* |
| *Clay (%)* | *-* | *32.19* |
| *Bulk density (gm/cc)* | *-* | *1.30* |
| *Field capacity (%)* | *-* | *35.98* |
| *Permanent wilting point (%)* | *-* | *21.96* |
| *Texture* | *-* | *Clay loam* |

*Uniformity coefficient.* In this study we compute statistical parameters and analyse uniformity of the subsurface drip system. The data pertaining to uniformity coefficient of drip irrigation system at different stages (01, 30, 60, and 90 DAS) of crop growth as influenced by different irrigation treatments and different emitter types as well as their interactions are presented in the Fig.1. There was significant effect of different irrigation treatments on the uniformity coefficient throughout the experiment, except at the end of experiment i.e. 90 DAS, there was not much difference in the uniformity under each treatment due to maintenance of automated drip system. The highest uniformity coefficient about was 97.09 per cent (01 DAS) was observed under TFWW. On the contrary there was no any significant effect among the different emitter types, hence the highest uniformity coefficient of 97.4 per cent was observed under Model C2.0 type emitter (01 DAS). On the contrary, lowest uniformity coefficient of 88.60 per cent (90 DAS) was observed under Model B2.0 type emitter. Uniformity coefficient of emitters was within permissible limit throughout the experiment due to regular maintenance of all the components of automated drip irrigation system. The special care was taken to increase the clogging resistance of emitters by regular chlorine and acid treatment. The similar results were observed by Capra and Scicolone (2004).

*Plant height.* Plant height is an important character of vegetative phase and indirectly influences the yield components. The data pertaining to plant height at different stages 15, 30, 60, and 90 DAS of crop growth was not influenced by different irrigation treatments and different emitter types as well as their interactions are presented in the Fig.4.

There was no significant effect of different irrigation treatments on plant height during all stages of plant growth. Under BWFW, highest plant height was 69.8 cm (60DAS) and lowest plant height was 14.4 cm (15DAS). But at harvesting stage i.e. after 90DAS the plant height was declining from 69.8 in TFWW and 67.6 cm in BWFW. This may be due to non-function able leaves and stem.

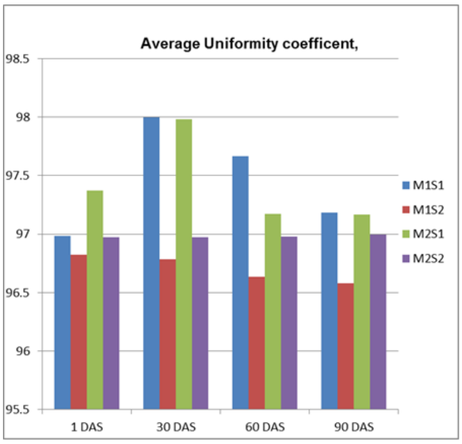


*Figure 2. Average Uniformity coefficient*

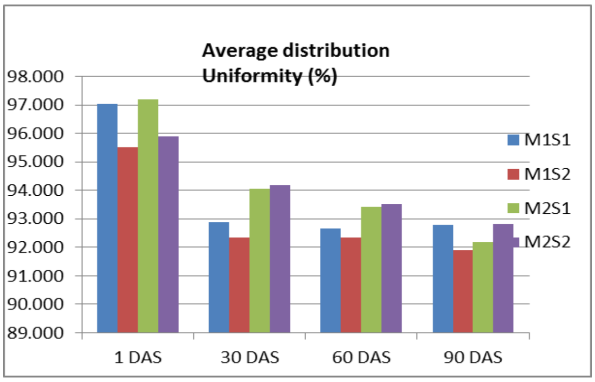


*Figure 3. Effect of different irrigation treatments on uniformity coefficient*

There was no significant effect of emitter types on plant height during all stages of plant growth. Under S1 emitter type, highest plant height was 69.8 cm (60DAS) and lowest plant height was 14.0 cm (15DAS) under S1 type emitter. But at harvesting stage i.e. after 90das the plant height was declining from 67.6 in M1 and 69.3 cm in M2. This may be due to non-function able leaves and stem. The interaction effects due to different irrigation treatments and emitter types on plant height during all stages of plant growth were found to be non-significant except S1 type of emitter at 15 DAS showed significant growth in plant height.

As a result of this may be due to the nitrogen, potassium nutrient increase the plant height. Higher nitrogen and potassium uptake in sandy clay loam soil is an evidence for this.

*Yield . Number of fruit per cluster.* The data pertaining to number of fruit cluster/ plant at different stages 45, 60 and 90 DAS of crop growth was influenced by different irrigation treatments and different emitter types as well as their interactions are presented in the Fig. 5.

There was no significant effect of different irrigation treatments on number of fruit cluster/ plant during all stages of plant growth. Under BWFW, highest number of fruit cluster/ plant of were 6.3 (60DAS) and lowest number of fruit cluster/ plant was 4.1 (45DAS). But at harvesting stage i.e. after 90DAS the number of fruit cluster/ plant was declining from 5.7 in TFWW and 6.2 in BWFW.

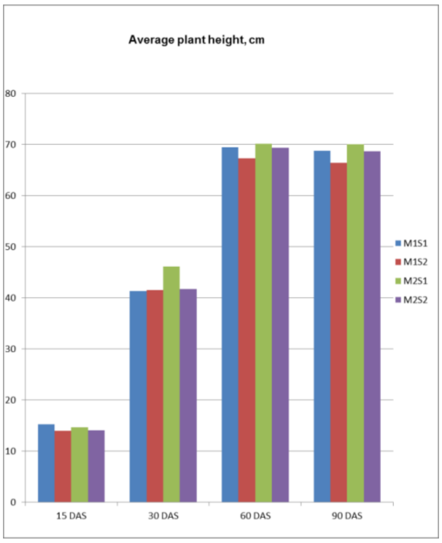


*Figure 4. Effect of different irrigation treatments on tomato plant height*

There was no significant effect of emitter types on number of fruit cluster/ plant during all stages of plant growth. Under S1 emitter type, highest number of fruit cluster/ plant was 6.1 (60DAS) and lowest number of fruit cluster/ plant was 2.9 (30DAS) under S2 type emitter. But at harvesting stage i.e. after 90DAS the number of fruit cluster/ plant was declining from 6.1 in S1 and 5.9 in S2.

The interaction effects due to different irrigation treatments and emitter types on number of fruit cluster/ plant during all stages of plant growth were found to be non-significant.

The data pertaining to weight per tomato influenced by different irrigation treatments and different emitter types as well as their interactions are presented in the Table 4.16 and Fig 4.10.

Non Significantly weight per tomato was observed under BWFW was about 81 gm. On the contrary, lowest weight per tomato 70 gm was observed under TFWW. Among the different emitter types, Non significantly highest weight per tomato 80.8 gm was observed under S2 type emitter. On the contrary, lowest weight per tomato was about 79.7 gm under S1 type emitter.

The interaction effects due to different irrigation treatments and emitter types on weight per tomato during all stages of plant growth were found to be non-significant. The data pertaining to grain yield influenced by different irrigation treatments and different emitter types as well as their interactions are presented in the Fig 3. Significantly highest Tomato yield was observed under BWFW was about 9.92 t ha-1.

On the contrary, but among treated waste water TFWW (8.34 t ha-1) has significant effect on tomato yield. Among the different emitter types, significantly highest tomato yield of 9.04 t ha-1 was observed under Model C2.0 type emitter. On the contrary, lowest tomato yield was 7.15 t ha-1 in Model B2.0 type emitter. Interaction effects due to different irrigation treatments and emitter types on tomato yield were found to be significant. The more difference in the tomato yield was observed in the BWFW followed by TFWW. The maximum tomato yield was observed in the Model C2.0 type emitter (10.56 t ha-1) in BWFW. This may be due the treated waste water was carrying impurities were affecting the emitter performance and still the pressure compensating emitter were better than non-pressure compensating emitter in case of uniformity. Also the treated waste water was adding macro as well as micro nutrient to the soil and which was available during its growth period. Similar findings was observed by Hassanli *et al.* (2010)

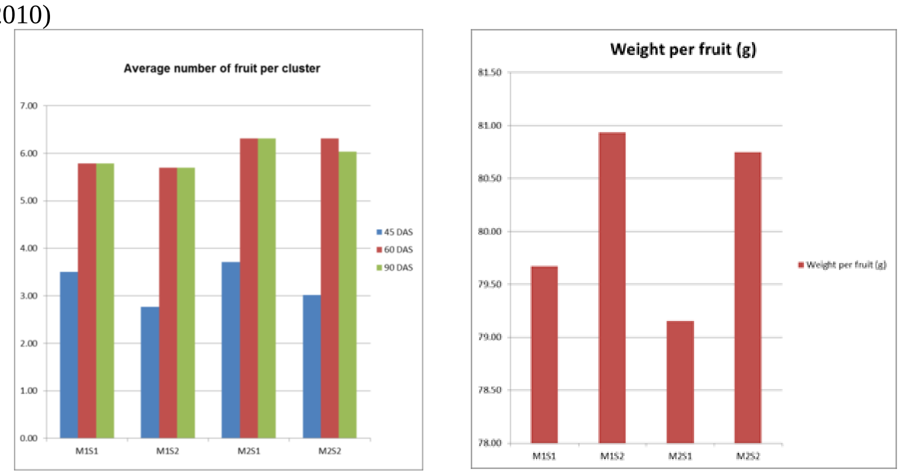


*Figure 5. Effect of different irrigation treatments on tomato yield*

*Quality parameters.* The influence of different irrigation treatments and different emitter types as well as their interactions on quality parameters of tomato such as protein, carbohydrates, fats, ash, crude fiber and energy are presented. Quality of Tomato depends on amount of protein, lycopene, fiber and carbohydrates content within it. TFWW is containing maximum amount of protein (0.92%). This may be due to the essential micro nutrient present in the treated waste water from fruit processing plant was available during growing period.

## CONCLUSIONS

- Please Model C2.0 type of emitter was having better performance throughout the experiment than Model B2.0 type emitter. It was observed that UC were more than 90 per cent for Model C2.0 type of emitter under TFWW and BWFW. Performance of automated drip irrigation system was within the permissible limit for TFWW, due to chlorine and acid treatment for BWFW.

- Maximum yield was obtained under Model C2.0 type emitter in BWFW; whereas minimum yield was obtained under Model B2.0 type emitter in TFWW.
- The yield obtained under TFWW was 31.01t ha-1 under Model C2.0 type emitter and yields obtained Model B2.0 type emitter used BWFW was 35.42 t ha-1 under the automated drip irrigation system.
- Maximum yield was obtained under Model C2.0 type emitter in BWFW; whereas minimum yield was obtained under Model B2.0 type emitter in TFWW.
- Percentage of protein, carbohydrates, lycopene, sugar and moisture content in the tomato was increased under treated fruit waste water.

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# UPOTREBA TRETIRANE OTPADNE VODE IZ PREHRAMBENE INDUSTRIJE U PROIZVODNJI PARADAJZA KROZ AUTOMATIZOVANO NAVODNJAVANJE

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***Sažetak:*** Voda je neophodna za sve forme života. Ovo istraživanje je izvedno radi provere održivosti primene tretirane otpadne vode iz prehrambene industrije u poljoprivredi. Ogled je postavljen na parcelama paradajza (*Lycopersican esculentum*) sa dva tretmana, tretirana otpadna voda od voća (M1) i sveža voda iz bušenog bunara (M2). Dva modela su izabrana, Model B2.0 (Bez kompenzacije pritiska – S2) i Model C2.0 (Pritisak kompenzacije – S1). Ispitivani su koeficijent ujednačenosti, visina biljaka, prinos, sadržaj proteina, likopena, vlakana i ugljenih hidrata. Rezultati su pokazali da je najviši koeficijent ujednačenosti (97.9 %) M1 (01 DAS), visina biljaka (69.82 cm) M1, prinos (35.42 $t \cdot ha^{-1}$), protein (0.92 %) M1 i likopen (4.28%) M2. Zaključeno je da tretirana otpadna voda može biti upotrebljena kao izvor za navodnjavanje posle sveže vode.

***Ključne reči****: otpadna voda, koeficijent ujednačenosti, tretirana otpadna voda, voda iz bunara, paradajz*

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# QUALITY CHARACTERISTICS OF MICROWAVE ASSISTED FLUIDIZED BED DRIED BUTTON MUSHROOMS (*Agaricusbisporus*)

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***Abstract:*** Microwave assisted fluidized bed drying can greatly improve the quality characteristics of button mushroom (*Agaricusbisporus*) slices. The quality attributes such as colour, texture, rehydration ratio and sensory score of dehydrated mushrooms using microwave assisted fluidized bed drying were compared with fluidized bed and sun dried products. Microwave assisted fluidized bed dried mushrooms had better quality characteristics with high rehydration potential, better colour and softer texture than other drying techniques. The shrinkage and rehydration ratio of microwave assisted fluidized bed drying varied between 67.115%-69.12% and 3.12%-4.59%, respectively. Similarly, the hardness value and cohesiveness varied between 1.24-1.63 N and 0.19-0.49, respectively. L*, a* and b* values of dehydrated button mushroom were range between 76.1-78.8, -1.09-3.76 and 7.01-11.01, respectively. The microwave-fluidized dried mushrooms showed higher sensory score by sensory panel in terms of appearance, color and overall acceptability.

***Key words****: button mushrooms, microwave-fluidized bed drying, rehydration ratio, shrinkage, sensory score*

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## INTRODUCTION

Mushrooms are non-green edible fungi which comprise a large heterogeneous group having various shapes, sizes, appearance and edibility. It plays an importance role in human diet due to the presence of protein, non-starchy carbohydrates and dietary fiber, minerals and vitamins. Button mushroom (100g) contains 1.8g protein, 0.5g fat, 0.4g carbohydrate, 0.2g sugar and 0.2g starch [1]. Button mushrooms are highly perishable as they contain moisture in the range of 6.75 to 18.9 kg/kg dry basis (87% to 95%, wet basis) [2]. Low fat content, absence of cholesterol and high fiber content makes mushroom dietician's choice for heart patients and also inhibit aromatase activity and suppress breast cancer cell proliferation The production of mushroom in India during the year 2013-14was 25000 tones.

Nowadays button mushroom have enormous post harvest losses, estimated nearly as 20 to 30% of total production[3]. So, there is a need to develop some processing techniques to reduce the post harvest losses.

Drying of button mushroom (*Agaricus bisporus*) is done by different methods viz. sun drying, tray and cabinet drying, fluidized/sprouted bed drying, microwave oven drying and freeze drying [4]

The factors that affects drying rate are temperature, thickness of button mushroom, method of drying and moisture diffusivity. Sulphitation followed by drying is one of the pretreatment methods for button mushrooms. The drying method used in this study is microwave drying followed by fluidized bed drying technique. The microwave treatment helps for the instant loss of moisture from the sliced mushrooms while the later drying technique showed faster rate of drying with retaining the quality of the dried product**.** The quality evaluation of the dried mushroom was done based on shrinkage, rehydration ratio, colour, texture and sensory evaluation.

## MATERIAL AND METHODS

The fresh button mushroom (4 cm size) without any defect was procured from Mushroom Research Centre, Pantnagar for the proposed study. It was washed thoroughly using potable water and soaked in 1.5% (Potassium metabisulphate) KMS solution for 15 min at room temperature for preservation. KMS preserves the natural colour of button mushroom and protects against bacteria. It was then blanched at 100°C with 3% common salt for 3 min in hot water to inactivate the enzymes and to retain the colour.

*Microwave oven dryer*: The drying apparatus used consisted of a microwave oven (Essential microwave oven fitted with National Magnetron with 800 Watts power and with 5 modes), which is operated at a 2450 MHz. The energy input was microprocessor controlled from 160W-800W.

*Fluidized bed dryer:* The fluidized bed dryer consist of a centrifugal blower, holding bin, heating coils, motor and thermostat control. The blower was centrifugal type with a capacity of $32 m^3$/min, run by a 3 hp, 3$\phi$ and 1400 rpm motor through a belt drive system. A sliding shutter was provided at the suction end to control the flow rate of air. Four fin type electrical heaters of 90 cm length were placed inside the drum. The thermostat at the discharge end measures the temperature of hot air and connected to the main supply to control the power supply to the heater coils. Hot air of 40-75$^0$C temperature at a flow rate of 9 to 32m$^3$/min could be obtained in the dryer.

*Experimental procedure:* After chemical pretreatment in KMS and sodium chloride, button mushroom pieces were dried in microwave oven dryer and fluidized bed dryer. The drying was carried out at different operating conditions of the dryer *viz.* drying time in microwave oven dryer, temperature and air velocity of fluidized bed dryer. The sun drying is also carried out simultaneously for the similar pretreated button mushrooms.

Shrinkage measurement:The button mushrooms were chopped into four equal pieces and its weight and bulk volume were measured. The same experiment was conducted for dried sample. Volumetric changes after dehydration of button mushroom pieces was measured by the liquid displacement method using liquid toluene.Shrinkage was expressed in terms of percentage change in the volume of the original sample.

$$Shrinkage = \frac{V_0 - V_t}{V_0} \times 100 \quad (1)$$

Where:

$V_0$ [ml] Initial volume,

$V_t$ [ml] Final volume.

*Rehydration ratio:* Rehydration ratio (RR), a measure of rehydration characteristics of dried mushroom slices was determined by immersing 5 g of dried samples in distilled water at 30 and 100$^0$C temperatures. The water was drained and the samples weighed at every 30 min intervals for those immersed at 30$^0$C and at every 2 min intervals for those at 100$^0$C. Triplicate samples were used. Rehydration ratio was defined as the ratio of weight of rehydrated samples to the dry weight of the sample

*Textural Measurement:* The textural properties of rehydrated button mushroom were determined according to the procedures outlined in the ASTM methods using a texture analyzer (Model TA.HD plus, United Kingdom) [5]. Samples were fixed on the plate of the equipment and probe P/75 was moved perpendicularly to the mushroom surface at a constant speed and the force-deformation were determined.

*Color Measurement:* For the measurement of colour of samples combination of digital camera, computer and Adobe Photoshop 7.0 software provides a less expensive and more versatile way to determine colour parameters of food products than traditional colour measuring equipments and also good colour of sample depends upon the intensity of light and distance between sample and camera. This colour measuring technique involves setting up a lighting system, high resolution digital camera to capture images of food samples[6].

The sample was placed under the source of light at minimum distance and intensity of light over the sample should be uniform for good quality colour. Digital camera (Sony 13 mega pixels) was used to capture the image of sample. The L*, a*, b* values of samples were measured by using Adobe Photoshop 7.0 software.

## RESULTS AND DISCUSSION

The optimized drying conditions for drying under microwave assisted fluidized bed drying and other drying methods viz., fluidized and suns drying are presented inTable.1.

The drying is carried out in microwave followed with fluidized bed drying, separate fluidized bed drying and sun drying. The optimization of drying parameters drying temperature, time and air velocity of mechanical dryers was done based on rate of moisture removal rate and quality of dried product.

*Table.1. Optimized drying parameter for drying of button mushroom*

| *S.No* | *Drying conditions* | *Microwave with fluidized bed dryer* | *Fluidized bed dryer* | *Sun drying* |
|---|---|---|---|---|
| *1.* | *Drying temperature (°C)* | *40* | *50* | *27 to 31** |
| *2.* | *Air velocity (m/s)* | *3.2* | *3.2* | *-* |
| *3.* | *Drying time (min)* | *2.7 and 60 to 65* | *210* | *5760* |
| *4.* | *Moisture content% (d.b)* | *8 to 9* | *8 to 9* | *23* |

* *Sun drying was carried out from 9 AM to 4 PM*

*Quality evaluation of button mushroom*: The quality evaluation of dried button mushrooms under optimized conditions of the three drying types is evaluated. The shrinkage, rehydration ratio, texture, colour and sensory analysis were done for the dried product and results are discussed below. The effect of drying parameters on the quality of the dried mushroom have been analyzed statistically using regression equation with modeling equation that fit to the curve and also analyzed graphically.

*Shrinkage*: Dried product usually shows the shrinkage due to the removal of moisture content. Dried product always contracted in size compared to the original material [7][8]. Volumetric shrinkage is a major parameter that affects the drying rate due to change in surface area. Hence to determine the volumetric shrinkage is essential.

The average shrinkage varied from between 67.11 to 69.12%. It was lower in case of 2.5 min drying in microwave oven dryer. The shrinkage of button mushroom was 79 and 75% in case of sun drying and fluidized bed drying respectively. Higher shrinkage was seen in sun drying and fluidized bed drying than microwave assisted fluidized bed dehydration. Similar result was reported by [9]button mushroom pieces dried by using vacuum drying. They concluded that over drying time and loss drying has more shrinkage than average drying time.

Shrinkage of button mushroom decreased from 67.9 to 65.8% with increasing air velocity (3.2 m/s) in fluidized bed drying keeping other variables (time and temperature) at optimum point. The graph Fig. 1. Presented below shows interactive effect of air velocity and temperature on shrinkage of button mushroom. Minimum shrinkage was obtained at optimum point of air velocity (3.2 m/s) at 42°C temperature while maximum shrinkage was obtained at air velocity (1.8 m/s) at 52°C temperature. From Fig. 2, at quadratic level, it is clear that the shrinkage of button mushroom decreased from 66.4 to 64.98 and increased from 64.98 to 67.2 with increasing drying time (3 min) in microwave oven dryer keeping variable (temperature and air velocity) at optimum point.

The rehydration property is important for the better market value and consumer acceptability of the dried mushrooms. It was analyzed in terms of the ability of the dehydrated button mushroom to regain the original product characteristics. Rehydration kinetics was studied for a period of 5 min at 100°C temperature. The result of rehydration ration was statistically analyzed using regression analysis. Second order mathematical model (Eq.6.) was fitted into the rehydration ratio data to analyze the effect of variables.

Fresh sample had moisture content of about 90.33% and it decreased with increase in temperature. The average rehydration ratio varied between 3.12 to 4.59. Similar result was found by[10].Rehydration ratio was higher in the case of 2.5 min drying in microwave oven dryer and it was 2.12 and 2.52 for sun drying and fluidized bed drying respectively. It was significantly lower in case of sun drying and fluidized bed drying than microwave assisted fluidized bed dehydration. This is attributing to less shrinkage of dried material. [10]Reported that the rehydration ratio of button mushroom dried using freeze drying was 3.416 and for microwave finish drying rehydration ratio was 2.850.

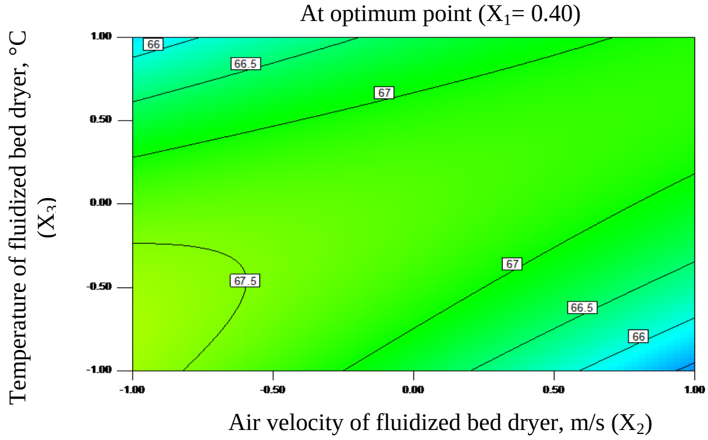


*Figure 1. Temperature versus air velociy of fluidized bed dryer at interactive level*

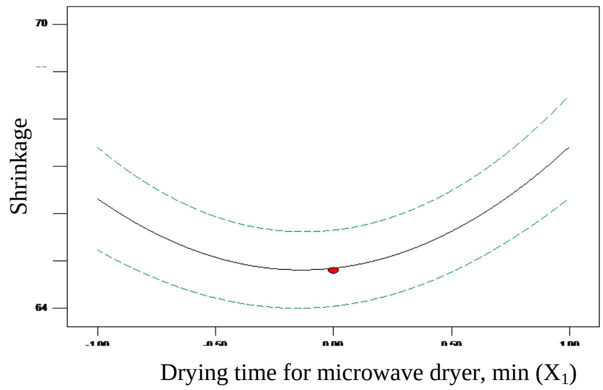


*Figure 2. Shrinkage versus drying time for microwave dryer at quadratic level*
*Rehydration ratio*

Total effect of individual parameter on rehydration ratio was calculated using the sequential sum of squares. It was observed that drying time for microwave oven dryer affected Rehydration ratio significantly at 1% level of significance, air velocity of fluidized bed dryer at 5% level of significance and temperature of the fluidized bed dryer affect 10% level of significance. Similar result was obtained by [11].

Second order predictive quadratic equation for Rehydration ratio (%) is given below:

$$Y = 4.34-0.039X_1-0.027X_2-0.18X_3+0.34X_1X_2 -0.030X_1X_3 +0.0074X_2X_3-0.74X_1^2 -1.10X_2^2 +0.15X_3^2 \quad (2)$$

Where:

$Y$ [-] Rehydration ratio,
$X_1$ [s] Drying time for microwave oven dryer,
$X_2$ [m/s] Air velocity of fluidized bed dryer,
$X_3$ [°C] Temperature of the fluidized bed dryer.

The interactive effect of air velocity and drying time on rehydration ratio of button mushroom. Maximum rehydration ratio was obtained at optimum point of drying time (2.5 min) at 3.2 m/s air velocity while minimum rehydration ratio was obtained at drying time 2 and 3 min in microwave oven dryer. It decreased from 3.49 to 4.5 and gradually decreased from 4.5 to 4.2 with increasing drying time in microwave oven dryer keeping other variables (air velocity and temperature) at optimum point.

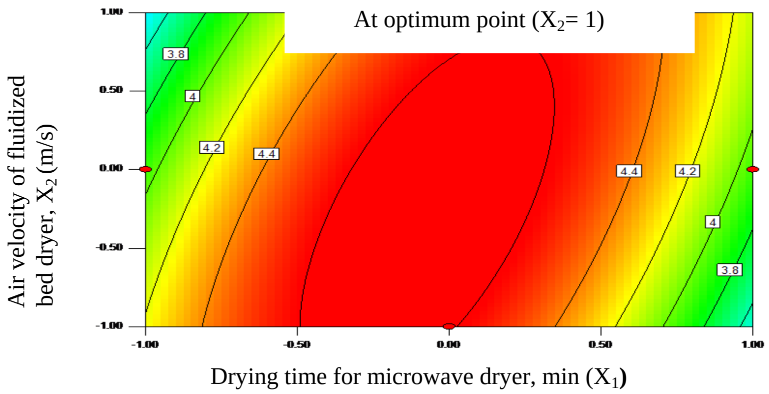


*Figure 3. Rehydration ratio versus temperature of fluidized bed dryer at linear level*

Texture characteristics: Texture characteristics of rehydrated button mushroom pieces were studied in terms of hardness and cohesiveness. Texture of button mushroom pieces was measured using Texture analyzer. The hardness value varied between 1.24 N to 1.63 N and cohesiveness varied from 0.19 to 0.49 for microwave assisted fluidized bed drying.[12]Observed the same trend of hardness and cohesiveness for rehydrated button mushroom. Hardness was 2.56 and 2.13 and cohesiveness was 0.07 and 0.10 in case of sun drying and fluidized bed drying respectively. The hardness was higher and cohesiveness was less in case of sun drying and fluidized bed drying than microwave assisted fluidized bed dehydration. It was also observed that hardness was increased and cohesiveness was decreased with increase in drying time and temperature.

It was observed that drying time for microwave oven dryer affected Hardness significantly at 1% level of significance, air velocity of fluidized bed dryer and temperature of the fluidized bed dryer affect 10% level of significance. Similar result was obtained by [13]. In the present study, effect of three variables on Hardness was observed.

The graph Fig.4. below indicates that hardness of rehydrated button mushroom is increased from 1.38 to 1.29 and increased from 1.29 to 1.63 with increasing in drying time in microwave oven dryer keeping other variables (air velocity and temperature) at optimum point. It also increases with increase in air velocity in fluidized bed dryer keeping at optimum point.

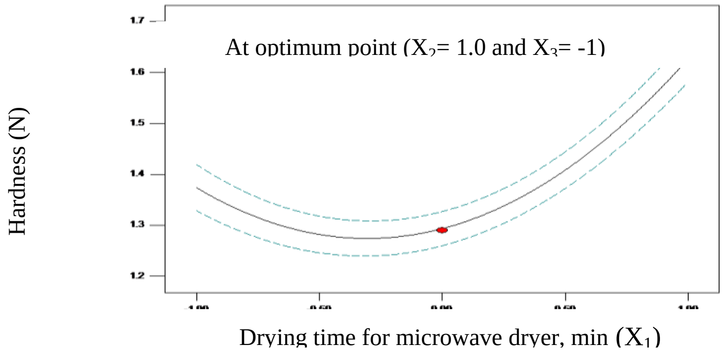


Figure 4. Hardness versus drying time for microwave dryer at linear level

The cohesiveness of rehydrated button mushroom increased from 0.32 to 0.46, decreased from 0.46 to 0.18 with increasing in drying time in microwave keeping other variables (air velocity and temperature) at optimum point. It increased from 0.39 to 0.41 andstart decreasing from 0.41 with increasing air velocity of fluidized bed dryer keeping other variables (drying time and temperature) at optimum point.

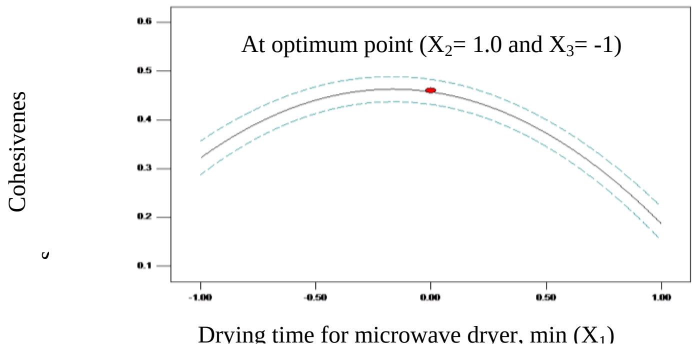


Figure 5. Cohesiveness versus drying time for microwave dryer at linear level

Colour characteristics: The colour of dried button mushroom indicates its quality of consumer acceptability pieces were measured in terms of L* value (darkness/brightness), a* value (greenness/redness) and b* value (blueness/yellowness). L*, a* and b* values of fresh button mushroom pieces was 85.2, 0.5 and 9.11. L*, a* and b* values of dehydrated button mushroom were range between 76.1 to 78.8, -1.09 to 3.76 and 7.01 to 11.01 respectively. Similar result was found by [14]. The L*,a* and b* of button

mushroom was 70.3,-1.20 and 8.02 in case of fluidized bed drying but L* was 72.8, a* was -1.29 and b* was 7.56 in sun drying. The sun dried product was dark than fluidized bed dried than microwave assisted fluidized bed dehydration.
The below figures give a clear difference in colour of sliced dried button mushrooms using different drying technique.

(a) (b) (c)

Figure 6. Dried sliced button mushroom (a) Microwave assisted fluidized bed dehydrated button mushroom; (b) Sun dried button mushroom; (c) Fluidized bed dried button mushroom

The L* value decreased from 78.6 to 77.6 with increase drying time in microwave oven dryer keeping other variables (air velocity and temperature) at optimum point.

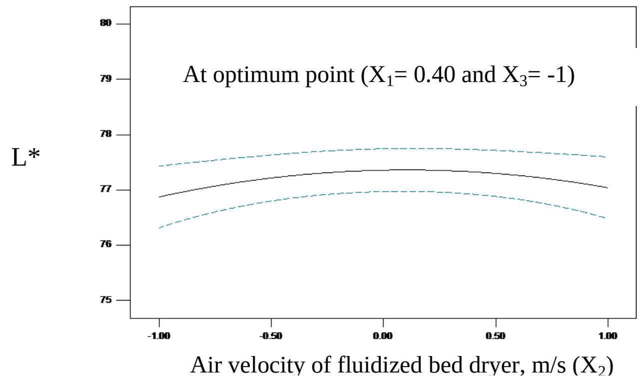


Figure 7. L* versus air velocity of fluidized bed dryer at quadratic level

The value of a* increased from -0.07 to 2.09 with increasing in microwave dryer and fluidized bed dryer other variables at optimum point. The b* value increased from 7.8 to 10.98 and decreased from 10.98 to 10.70 in microwave dryer and increased from 9.48 to 10.97 in fluidized bed dryer, this may be significantly influenced by optimum drying temperature[15] .

## CONCLUSION

Button mushroom is highly perishable in nature; therefore, its shelf life needs to be extended to use it during off season. It has a very high level of moisture content hence it needs preservation. Dehydration is the most important method for preservation of button mushroom with an ultimate aim of improving storability by reducing its moisture content. Removal of water from button mushroom prevents microbial growth and thus makes storage without refrigeration possible. Microwave assisted fluidized bed drying of mushroom was much faster thanfluidized bed and sun drying.Particularly towards the end of the drying process

Result of the study shows thatmicrowave assisted fluidized bed dried mushroom created a more porous dehydrated product, shrinkage slightly reduced then rehydrated more quickly. The hardness was lower and cohesiveness was higher for microwave assisted fluidized bed dried. The drying time range from 60 to 65 min for microwave assisted fluidized bed drying whereas 210 min for separate fluidized bed was drying and 4 days for sun drying to dry the button mushroom up to 23.00% moisture content (d.b.).The shrinkage and rehydration ratio of microwave assisted fluidized bed dried mushroom varied from 67.11 to 69.12%. and 3.12 to 4.59.whereas shrinkage of button mushroom was 79 and 75% in case of sun drying and fluidized bed drying respectively. The rehydration ratio for sun drying and fluidized bed drying 2.12 and 2.52 respectively. It is concluded that the quality of the dried button mushroom was high in case of microwave assisted fluidized bed dryer.

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## KVALITATIVNE KARAKTERISTIKE MIKROTALASNOG SUŠENJA PEČURKI U FLUIDIZOVANOM SLOJU (*Agaricusbisporus*)

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***Sažetak:*** Mikrotalasno sušenje u fluidizovanom sloju može značajno da unapredi kvalitet pečurki (*Agaricusbisporus*). Kvalitativne osobine kao što su boja, tekstura, odnos rehidracije i ukus dehidriranih pečurki su poređene sa pečurkama sušenim na suncu. Mikrotalasno sušenje je dalo bolji kvalitet sa velikim potencijalom rehidracije, lepšom bojom i mekšom teksturom nego druge tehnike sušenja. Skupljanje i odnos rehidracije bili su 67.115% - 69.12% i 3.12% - 4.59%, redom. Slično, tvrdoća i kohezija su iznosili 1.24 - 1.63 N i 0.19 - 0.49, redom. L*, a* i b* vrednosti dehidriranih pečurki su iznosile 76.1 - 78.8, -1.09 - +3.76 and 7.01 - 11.01, redom.

***Ključne reči****: pečurke, mikrotalasno sušenje u fluidizovanom sloju, odnos rehidracije, skupljanje*

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# VARIATIONS IN EXPLOITATION CHARACTERISTICS OF TRACTORS DEPENDING ON PRE-IGNITION ANGLE OF THE ENGINE

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***Abstract***. Maintenance of tractors on small private farms in Bosnia and Herzegovina is not given sufficient and adequate attention. Consequences of such a trend reflect on exploitation characteristics of tractors, significantly increases fuel consumption and environmental pollution. The goals of the research focused on the part of the issue related to the influences of different pre-ignition angle of the engine on the available power at the PTO shaft and increase of the specific fuel consumption. The research was conducted in the laboratory and experimental facilities of the agricultural machinery testing station in 2015 at the Butmir range, Sarajevo. The obtained results indicate that the tractor power at PTO shaft varied from 21kW do 45kW, that is in a range from 46.6 - 100 %. Variation of the engine power caused changes in fuel consumption which in the plough mode varied from 4.01- 6.86 kg·h$^{-1}$ of fuel (D-2). Cost-wise, this influenced variations from 2.25 to 4.72 €·h$^{-1}$ in the idle mode (stand gas) and from 5.57 to 8.81€·h$^{-1}$ in the plough mode. The obtained results confirmed the hypothesis that regular maintenance in accordance with manufacture's standards needs to be implemented; otherwise the costs of consequences will exceed the maintenance costs several times.

***Key words***: *tractor, maintenance, engine power, fuel consumption.*

## INTRODUCTION

In order to understand the importance of the pre-ignition for the process of combustion of fuel in diesel engines, one needs to be familiar with the overall process of

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supply, purification and combustion. It is understandable that manufacturers of engine continuously strive to improve the combustion system in other to better utilize the energy potential of the fuel. More recent generations of engines have computer controller combustion systems. However, in practice, hydro-mechanic systems of distribution of fuel are still dominant in agriculture tractors. The quantities are does through a high pressure pump which can be of rotary or linear type, but the deviations of the fuel quantity per cylinder should not exceed ±2%. In the case of such older types of engines, Kozarac et al. [3] the time for injection of fuel is limited to a period from 1/300 to 1/800 parts of second. Computer controlled engines (*„Common Rail“*) have a much higher injection pressure (up to 2,000 Bar), and the injection velocity is measured in thousandths of a second.

Technical designs of engines continuously follow the perfecting of the quality of fuel Šilić et al. [6] which are expressed in respective cetane number, that is a ratio between the volume of fast burning cetane (n-hexane) and the volume of slow burning cetane (á- *Methylnaphthalene*). The process of combustion also depends on physical-chemical features of the diesel fuel such as, viscosity, chemical stability, percentage of sulphate, etc. Depending on the working conditions of the engine different additive are added to the fuel to enhance the combustion process, prevent solidification of paraffin, improve the chemical stability, prevent development of soot and tar pitch, which contaminate the environment and partly remain in the engines.

Bearing in mind the listed characteristics of engines and fuels, special attention needs to be given to regular maintenance which can significantly influence the performance. The pre-ignition angle of the engine can be one of the reasons for improper combustion of fuel. Therefore the goal of the research is to draw attention to the negative consequences of this factor and the requirement to do regular maintenance.

## MATERIAL AND METHODS

The research was done in laboratories and experiment stations using a Zetor model 63.41 tractor assembly with double reversible plow. The part of the research done in the laboratories was related to different levels of adjustment of the pre-ignition angle and measuring of power with electric brake at PTO shaft and was conducted at the Testing station for agriculture machines of the Agriculture and Food Sciences Faculty in Sarajevo. The adjustments of the pre-ignition angle were done using the comparative and goniometric method for adjustment of angle. The goniometric method implied adjusting the pre-ignition angle with a comparator, and the comparative method implied a use of a template used also in the testing of exploitation characteristics of the tractor assembly. The following levels of adjustment of pre-ignition angle were applied:

A - Deviation of up to 10% (-17.8$^0$ early ignition /A´/; -16.2$^0$ late ignition /A″/);

B - Deviation of up to 20% (-19.5$^0$ early ignition /B´/; -14.5$^0$ late ignition /B″);

C - Deviation of up to 30% (-20.4$^0$ early ignition /C´/: -12.7$^0$ late ignition /C″/);

K - Adjustments made according to manufacturer's regulations (Control).

Any deviation of the pre-ignition angle in comparison to the manufacturer's norm of 17$^0$ reflects on the power of the engine and other exploitation characteristics of the tractor. By calibrating the high pressure pump to inject fuel prior to 17$^0$ causes a change in the work of the engine, which is manifested in a way that the engine is noisier and has seemingly bigger power.

The experimental part of the research included measuring of fuel consumption during ploughing. The volumetric method of consumption expressed in liters was applied, specifically consumption per units surface area (L/ha) and specific consumption (g/kwh) Lulo et al. [4]. The volumetric method was the basis for calculation of the other two forms of listed consumption. The volumetric consumption was translated into mass consumption through application of the following formula:

$$q=V[l]\cdot\delta\ [kg\ m^{-3}] \quad (1)$$

The results obtained from conducted measuring were processed with application of standard mathematical-statistic methods, presented in appropriate tabular breakdowns and graphs and discussed in relation to results obtained by other authors. In the work we applied the Spearman's *correlation coefficient*, which is often used for measuring of the relations among variables and when it is not possible to apply the *Pearson's correlation coefficient*.

## RESULTS AND DISCUSSION

In case of a tractor engine with a properly adjusted high pressure pump the engine had an average engine power of 39.04 kW, and the average torque of 189.65Nm, and the average number of Rotation at the PTO shaft of 511.35 min$^{-1}$. Other statistic indicators are given in Table 1.

*Table 1. Indicators of tractor performance at a pre-ignition angle of 17$^0$ (K control)*

| *Pre-ignition angle 17$^0$ (K- control)* | *$N_0$* | *Min.* | *M ax.* | *Mean* | *Std. Deviation* | *Variance* | *Skewness* |
|---|---|---|---|---|---|---|---|
| *Rotation on PTO (min$^{-1}$)* | *23* | *384* | *609* | *511.35* | *73.61* | *5418.78* | *-0.31* |
| *Torque (Nm)* | *23* | *97* | *230* | *189.65* | *37.81* | *1429.68* | *-0.99* |
| *Power on PTO shaft (kW)* | *23* | *24* | *45* | *39.04* | *5.07* | *25.77* | *-1.60* |

*No – Number of measurements';*
*Skewness - measure of asymmetry data.*

The simulation of movement of high pressure pump to an early ignition phase of up to 10% reflected on reduction of the average power of the engine to 38.33 kW, lower average torque of 174.78 Nm, as well as a lower average number of Rotation on the PTO shaft, which was at the level of 543.27 min$^{-1}$.

*Table 2. Indicators of tractor performance at a 10% deviation of the pre-ignition angle*

| *Deviation of 10% (A′ and A″)* | *Angle* | *$N_o$* | *Min.* | *Max.* | *Mean* | *Std. Deviation* | *Variance* | *Skewness* |
|---|---|---|---|---|---|---|---|---|
| *Rotation on PTO (min$^{-1}$)* | *17.8$^0$* | *30* | *368* | *615* | *543.27* | *74.34* | *5527.65* | *-1.13* |
| | *16.2$^0$* | *30* | *370* | *613* | *543.20* | *74.19* | *5504.50* | *-1.12* |
| *Torque (Nm)* | *17.8$^0$* | *30* | *96* | *226* | *174.78* | *5.23* | *1241.71* | *-0.44* |
| | *16.2$^0$* | *30* | *96* | *224* | *174.72* | *5.29* | *1245.82* | *-0.44* |
| *Power on PTO shaft (kW)* | *17.8$^0$* | *30* | *24* | *44* | *38.33* | *5.12* | *26.29* | *-1.16* |
| | *16.2$^0$* | *30* | *24* | *44* | *38.40* | *5.16* | *26.66* | *-1.17* |

When the high pressure pump was moved to the late ignition phase of up to 10% it caused a reduction in the average power of the engine to 38.40 kW and a smaller average torque at the level of 174.72 Nm. The average number of Rotation at the PTO shaft totaled 543.20 min$^{-1}$. When the high pressure pump was in the position of an early ignition phase (10-20%) it caused a reduction of average power of the engine to 36.30kW and a lower torque, which was at the level of 162.42Nm. In such a position of the pump the average number of Rotation at the PTO shaft totaled 552.10 min$^{-1}$.

*Table 3. Indicators of tractor performance at a 10-20% deviation of the pre-ignition angle*

| Deviation of 10-20% (B–early; B-late) | Angle | $N_0$ | Min. | M ax. | Mean | Std. Deviation | Variance | Skewness |
|---|---|---|---|---|---|---|---|---|
| Rotation of PTO (min$^{-1}$) | 19.5$^0$ | 30 | 424 | 615 | 552.10 | 60.95 | 3715.33 | -0.73 |
| | 14.5$^0$ | 29 | 401 | 620 | 552.00 | 67.50 | 4556.38 | -0.84 |
| Torque (Nm) | 19.5$^0$ | 30 | 93 | 208 | 162.42 | 32.58 | 1061.69 | -0.50 |
| | 14.5$^0$ | 29 | 95 | 224 | 162.43 | 37.71 | 1422.59 | -0.42 |
| Power on PTO shaft (kW) | 19.5$^0$ | 30 | 23 | 41 | 36.30 | 5.00 | 25.04 | -1.22 |
| | 14.5$^0$ | 29 | 24 | 43 | 36.48 | 5.55 | 30.83 | -1.27 |

Positioning of the high pressure pump to a late ignition phase (10-20%) influences a reduction of average power of the engine (36.48kW) and a lower average torque (162.43 Nm). In the respective position of the pump the average number of Rotation on the PTO shaft was 552.00 min$^{-1}$. After shifting the high pressure pump to the early ignition phase (20-30%) the average power of the engine was reduced to 34.48kW, torque to 149.43Nm, and the number of Rotation at the PTO shaft was je 539.03min$^{-1}$.

*Table 4. Indicators of tractor performance at a 20-30% deviation of the pre-ignition angle*

| Deviation 20-30% (C–early; C-late) | Angle | $N_0$ | Min. | M ax. | Mean | Std. Deviation | Variance | Skewness |
|---|---|---|---|---|---|---|---|---|
| Rotation on PTO (min$^{-1}$) | 20.40$^0$ | 30 | 411 | 602 | 539.03 | 60.95 | 3715.33 | -0.73 |
| | 12.75$^0$ | 29 | 396 | 615 | 543.21 | 67.50 | 4556.38 | -0.84 |
| Torque (Nm) | 20.40$^0$ | 30 | 80 | 194 | 149.43 | 32.58 | 1061.69 | -0.50 |
| | 12.75$^0$ | 29 | 86 | 215 | 156.62 | 37.77 | 1426.67 | -0.43 |
| Power on PTO shaft (kW) | 20.40$^0$ | 30 | 21 | 40 | 34.48 | 5.01 | 25.11 | -1.24 |
| | 12.75$^0$ | 29 | 22 | 41 | 34.52 | 5.48 | 30.11 | -1.30 |

Shifting of the high pressure pump to the late ignition phase (20-30%) reduced the average power of the engine to 34.52 kW and the average torque to 156.62 Nm. The average number of Rotation at the PTO shaft was 543.00 min$^{-1}$. After shifting the high pressure pump to late ignition mode (above 17$^0$) the tractor worked more quietly (seemingly nice sound of the engine) but its power declined. The power of the tractor engine in case of a deviation of the pre-ignition angle of up to 10% caused a reduction of the power at the PTO shaft by 0.85 kW, deviation of between 10 to 20 % cause a reduction of power by 2.7 kW and a deviation of the pre-ignition angle at the level from 20 to 30% caused a reduction of power by 4.66 kW. Asymmetrical data processed by skewness method was in the range -1.16 to -1.60.

In case of diesel engines, shifting of the angle caused tapping in the engine as well as a delay in ignition of fuel. In the late ignition phase the combustion of fuel was incomplete. Researches done by other authors noted the same occurrence. According to Šilić et al. [6] delays in combustion that exceed 0.002 seconds, result in a bigger quantity of fuel in the combustion area and causes rapid (peak) combustion which is accompanied with strong noise. Continuation of the analysis of the described occurrence shows (Fig. 1) that tapping (throbbing) in the engine causes an additional increase in pressure, but negatively reflects on the noise and vibrations.

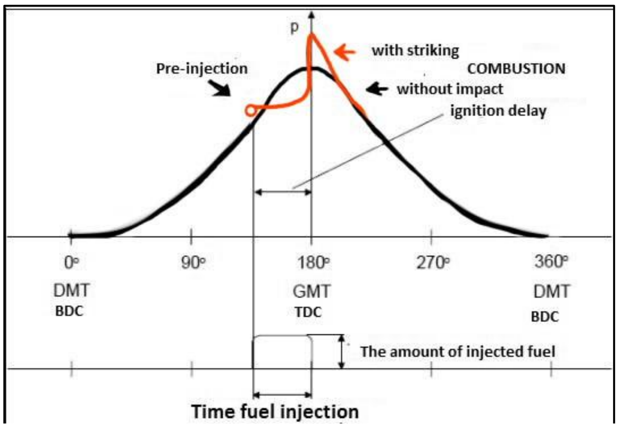


*Figure 1. Combustion process in a diesel engine (taken over)*

Shifting of the high pressure pump from the optimum pre-ignition area reflects on exhaust gases. Specifically the engine exhausts gases of black or white color. The combustion process takes place in all diesel engines and is higher in the case of high-speed engines than in the case of low-speed engines. Eriksson [2] in his dissertation stipulates that early ignition time produces a pressure of so called "early development", which results in a sudden increase of pressure which can be considered as an early expansion.

The usual period of combustion of fuel in engines Kozarac et al. [3] various from 0.0007 to 0.003 seconds. If the period of concealed combustion is too big (exceeds 0.002 sec), then a larger amount of fuel is accumulated in the combustion area, which will ultimately lead to the simultaneous combustion of fuel. The consequence is that the pressure and temperatures rapidly increase above the usual values. This occurrence is often called "peak combustion" or "rigid work" of the diesel engine. Peak combustion is not desirable because it burdens parts of the engine mechanism and can cause negative consequences.

The testing of the influence of the pre-ignition angle on the power of the engine and the torque were confirmed by the positive correlation factors. Correlations between the engine power and the size of the angle of the high pressure pump were at the level of 0.01 and 0.05. Correlations with the torque were at the level of 0.01.

*Consumption of fuel depending on the pre-ignition angle.* The analysis of fuel consumption revealed that deviation from manufacturer's norm ($17^0$) result in significant increase of fuel consumption. Results obtained are presented in Table 5.

Deviations of the pre-ignition angle in relation to the manufacturer's norm ($17^0$) caused significant increase in fuel consumption. The biggest increase in fuel consumption was recorded in the „C-late" case and amounted to 1.91 kg/h that is by 109.12%. The presented indicators confirm that work with technically irregularly tuned tractor engine can exceed multiple times the costs of regular maintenance. As for the exploitation indicator of fuel consumption, other authors obtained similar results. In example, in their research Filipovic et al. [1] stipulated that the change of working speed in the ploughing mode from 5 km/h to 7 km/h increased consumption for 10.32%; Mileusnic et al. [5] stipulated that during ploughing at 30 cm the fuel consumption varied from 26-36 l/ha, or when calculated in percentages this means that consumption increased by 38.46%.

*Table 5. Fuel consumption in relation to pre-ignition angle*

| *Pre-ignition* | *Fuel consumption (kg)* | | *Increase in fuel consumption (%)* | |
|---|---|---|---|---|
| | *Stand gas 800 min$^{-1}$* | *Ploughing (1500 min$^{-1}$)* | *Stand gas 800 min$^{-1}$* | *Ploughing (1500 min$^{-1}$)* |
| *Manufacturer's norm (17$^0$)* | *1.75* | *4.01* | *0* | *0* |
| *10% Deviation (A-early)* | *1.95* | *4.38* | *11.11* | *9.20* |
| *10% Deviation (A-late)* | *2.02* | *4.53* | *15.10* | *12.94* |
| *20% Deviation (B-early)* | *2.80* | *5.78* | *59.54* | *44.10* |
| *20% Deviation (B-late)* | *3.07* | *5.66* | *74.93* | *41.11* |
| *30% Deviation (C-early)* | *3.51* | *6.58* | *99.72* | *64.05* |
| *30% Deviation (C-late)* | *3.67* | *6.86* | *109.12* | *71.03* |

*Table 6. Fuel costs in relation to pre-ignition angle*

| *Pre-ignition angle* | *Fuel consumption (€/h)* | |
|---|---|---|
| | *Stand gas 800 min$^{-1}$* | *Plough 1500 min$^{-1}$* |
| *Manufacturer's norm (17$^0$)* | *2.25* | *5.16* |
| *10% Deviation (early)* | *2.50* | *5.63* |
| *10% Deviation (late)* | *2.59* | *5.82* |
| *Up to 20% Deviation (early)* | *3.59* | *7.43* |
| *Up to 20% Deviation (late)* | *3.94* | *7.27* |
| *Up to 30% Deviation (early)* | *4.50* | *8.46* |
| *Up to 30% Deviation (late)* | *4.72* | *8.82* |

*Effect of pre-ignition angle on fuel costs.* The level of technical education of a large number of farmers is not at the level that would enable them to fully grasp the presented results of the research. If the obtained results are transformed and expressed as a loss of money then the farmers get a much clear picture of the importance of this issue. Definition of fuel consumption can be used to calculate the costs that are directly correlated. The fuel costs are calculated on the basis of the price of diesel fuel in BiH, which currently is at the level of 2.10 KM/l (1.07 €). Breakdown of fuel costs in relation to the pre-ignition angle is given in Table 6.

In case of fine-tuned pre-ignition angle, fuel costs totaled 2.25 €/h on stand gas (idle mode) and 5.16 €/h in plough mode. After shifting the angle (deviation, A-early, up to 10%) the fuel costs totaled 2.50 €/h, that is 5.63 €/h in the plough mode. Fuel costs increased with the simulated deviation from the prescribed pre-ignition angle. In the plough mode in case of a 20.4$^0$ pre-ignition angle the difference in fuel consumption in relation to manufacturer's norm (17$^0$) was at the level of 3.67 €/h.

In case of early pre-ignition with a deviation of 19.5$^0$ before the upper dead center, in comparison to the normally tuned ignition, fuel costs totaled 3.59 €/h at 800 min$^{-1}$ in the plough mode, and at 1500 min$^{-1}$ the value was doubled and totaled 7.43 €/h.

## CONCLUSIONS

On the basis of conducted research which encompassed laboratory work, field work, research of literature and processing of data we draw the following conclusions:

- The average power of tested tractor engine with a fine-tuned pre-ignition angle totaled. 39.04kW. After simulated shifting of the pre-ignition angle the engine power significantly decrease and reached the following values:
  - In case of an early and late pre-ignition with an up to 10% deviation the average power totaled 38.33 kW;
  - In case of early pre-ignition (20% deviation) the average power totaled 36.30 kW, while in the case of late pre-ignition (20% deviation) the average power totaled 36.48 kW:
  - In case of early pre-ignition (30% deviation) the average power totaled 34.48 kW, while in the case of late pre-ignition (30% deviation) the average power totaled 34.52 kW.
- The effect of the pre-ignition angle on fuel consumption was tested in the stand gas (idle mode) (800 o/min$^{-1}$) and the plough mode (1 500 o/min$^{-1}$). In case of a normally tuned pre-ignition angle the consumption at 800min$^{-1}$ was 1.75 kg/h, and at 1500 min$^{-1}$ it totaled 4.01 kg/h. After simulated shifting of the pre-ignition angle the fuel consumption significantly increased. The following values were recorded:
  - 10% deviation (A-early), consumption at 800min$^{-1}$ was 1.95 kg/h, and in the plough mode at 1500min$^{-1}$ 4.38 kg/h;
  - 10% deviation (A-late), consumption at 800min$^{-1}$ was 2.02 kg/h, and in the plough mode at 1500min$^{-1}$ 4.53 kg/h;
  - 20% deviation (B-early), consumption at 800min$^{-1}$ was 2.80 kg/h, and in the plough mode at 1500min$^{-1}$ it was 5.87 kg/h;
  - 20% deviation (B-late), consumption at 800min$^{-1}$ was 3.07kg/h, and in the plough mode at 1500min$^{-1}$ 5.66 kg/h;
  - 30% deviation (C-early), consumption at 800min$^{-1}$ was 3.51 kg/h, and in the plough mode at 1500min$^{-1}$ 6.58 kg/h;
  - 30% deviation (C-late), consumption at 800min$^{-1}$ was 3.67 kg/h, and in the plough mode at 1500min$^{-1}$ 6.86 kg/h;
- Financial indicators of fuel consumption varied from 2.25 to 4.72 €/h with no load on stand gas and from 5.57 to 8.81 €/h in plough mode with a double furrow plough.

The obtained results confirmed the hypothesis that servicing of agriculture tractors should be done regularly and in accordance with manufacturer's norms as otherwise the consequences will exceed several times the costs of regular maintenance.

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## PROMJENA EKSPLOATACIONIH SVOJSTAVA TRAKTORA U ZAVISNOSTI OD UGLA PREDPALJENJA MOTORA

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***Sažetak:*** Održavanju traktora na malim privatnim posjedima u Bosni i Hercegovini ne posvećuje se dovoljna pažnja. Posljedica takvog stanja odražava se na eksploataciona svojstva traktora, te značajno povećava potrošnju goriva i zagađenje okoline. Ciljevi istraživanja fokusiraju se na dio problematike koja sagledava uticaj različitog ugla predpaljenja motora na raspoloživu snagu traktora na priključnom vratilu (PTO) i povećanje specifične potrošnje goriva. Istraživanja su izvedena u laboratorijskim i eksperimentalnim uslovima ispitne stanice za poljoprivredne mašine u Sarajevu, na destinaciji “Poligona Butmir” u 2015. godini. Dobiveni rezultati ukazuju da je snaga traktora na PTO varirala u rasponu od 21kW do 45 kW, što u procentualnim pokazateljima iznosi 46,6 - 100 %. Varijacije snage motora prouzrokovale su promjenu potrošnje goriva koja je iznosila u oranju od 4,01- 6,86 $kg \cdot h^{-1}$ nafte (D-2), dok se navedena potrošnja goriva u finansijskim pokazateljima kretala u rasponu od 4,41 do 9,23 $KM \cdot h^{-1}$ na štandgasu i od 10,9 do 17,23 $KM \cdot h^{-1}$ u oranju. Dobiveni rezultati su potvrdili hipotezu da servisiranje poljoprivrednih traktora treba izvoditi redovno i prema tvorničkim normativima, u protivnom posljedice višestruko nadmašuju troškove servisiranja.

***Ključne riječi:*** *traktor, servisiranje, snaga motora, potrošnja goriva.*

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