Interaction Effect of Operating Parameters of Rotary Tiller Blade on Tillage Quality under Soil Bin Condition

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Abstract - *The blade shape, operating parameters and soil physical properties are the key parameters come to pronouncement for pulverizing soil condition. J shape rotavator blades was tested in the laboratory under soil bin condition for medium textured soil at controlling soil physical properties namely moisture content (15±1 %), bulk density (1.20±1 g/cm3) and Cone Index (80±12 kPa).The performance results were analyzed in terms of tilling quality of soil with the effects of three operating parameters namely tilling depth, forward speed and rotary speed. Experiments were designed by design expert software for central composite randomized design and statistically analyzed and evaluated by response surface methodology. The average values of soil mean mass diameter for J shape rotavator blades was found to be 2.31 mm with their optimum tilling depth, forward speed and rotary speed were found to be 100 mm, 400 rpm and 2.0 km/h respectively.*

Key Words: J shape rotavator blade, soil bin, soil physical properties, operating parameters, tilling quality, design expert software, response surface methodology.

1. INTRODUCTION

Tillage is the most important unit operation in agriculture. It is done mainly to loosen the upper layer of soil, to mix the soil with fertilizer and to remove weeds. As a result of this processing the water-air, thermal and nutrient regimes of the soil are improved in the interest of the growth and development of crops. Rotavator mixes and pulverizes the tilled soil well; resulting in a good clod size distribution.

The number of tillages passes required to achieve an acceptable tilth quality, using rotavator is also significantly reduced (Makange, 2015) in comparison to the series of operations that would result in the same tilth quality with the use of passive tools. Also (Subrata et al., 2014; Rajesh et all., 2018) conducted research on the soil-blade interaction of a rotary tiller under soil bin condition.

Soil bin is a generic term for a test facility for studying soil dynamics, especially on the soil machine interaction research in agriculture. Generally, a soil bin facility consists of soil bin, tool carriage, processing trolley, drive system, instrumentation and data acquisition systems (Mandal et al. 2014). The application of soil bin for soil machine interaction research was initially established by several research institutes, such as the National Tillage and Machinery Laboratory (NTML) in the United States of America (NRAM, 1983). Ideally, in the field, the moisture content varies throughout the entire field as it is not under controlled condition. But in a soil bin moisture content can be controlled as per the requirement. The water content of the soil is an important property that controls its behavior. Usually, the soil parameters in soil bins such as variation of cone index and soil compaction level may be kept constant (Mardani et al. 2010 and Rajesh et all., 2018).

Looking to the present practice of seed bed preparation among the farmers and the implements used to perform different operations, there is a need to find out the suitable alternative either operation wise or equipment wise by which cost of operation can be reduced and efficiency of the cropping system can be improved. In this research, performance of rotavator with J shape blades has been evaluated and compared based on soil tillage quality at different operating parameters by maintained soil physical properties under soil bin condition for medium textured soil.

2. MATERIALS AND METHODS

Laboratory experiments were conducted in the College of Agricultural Engineering and Post Harvest Technology, Central Agricultural University, Ranipool, Sikkim state India. All laboratory tests were carried out as per the recommendation of the Regional Network for Agricultural Machinery (RNAM, 1983).

2.1 Moisture content

Moisture content of the soil was determined by oven drying method. Three samples were taken from the different locations of the test area in different moisture boxes. These were kept in oven for 24 hours at the temperature of 105 ºC. The mass of wet and dry samples were determined and average moisture content on dry basis calculated.

Moisture Content (% db) = $(Ww - Wd)/Wd$ **1**

where, W_w = Weight of wet soil, and W_d = Weight of dry soil.

2.2 Bulk Density

Bulk density of soil was calculated by using following standard formula:

Bulk density of soil = $\frac{W}{V}$ **2**

where, W = Weight of dry mass of soil (g) and V = Volume of metallic core (cm^3).

2.3 Soil mean mass diameter

For determining the Soil Mean Mass Diameter (SMMD) soil sample was allowed to pass through a set of sieves (electric powered sieve shaker). Weighed the soil retained on the different aperture sizes of sieve (2, 2.8, 4.0, 5.6, 8.0 and 11.2). SMMD was calculated using the following formula: (Mehta et al.,1995).

$$\mathrm{SMMD} = \frac{(A + 2.4B + 3.4C + 4.8D + 6.8E + XF)}{W}$$ 3

Where, X = mean of measured diameter of soil clods retained on the largest aperture sieve, W = the total weight of the soil sample and A, B, C, D, E and F = weight of soil retained at each sieve (kg).

2.4 Cone Index

Cone index is an indication of soil hardness and is expressed as force per unit area required for penetrating a cone into the soil. Cone index was measured by using cone penetrometer up to a depth of 134 mm. The diameter and height of cone were measured and then surface areas of cone was calculated by using the following formula:

Surface area of cone, $A=\pi rl+\pi r^2$ **4**

Where, r = Radius of cone, and l = Slant height of cone.

Cone penetrometer was calibrated first, in the laboratory, for the applied known weights and a linear relationship was found as shown in Fig -1.

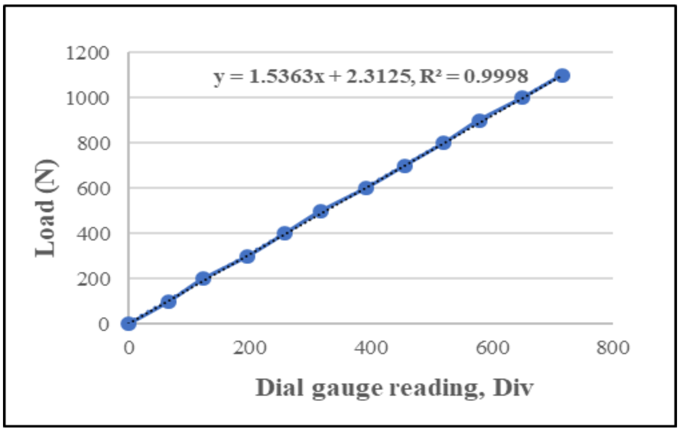

Fig-1: Calibration of the cone penetrometer (dial gauge type)

2.5 Statistical analysis

The laboratory data were statistically analyzed by Design Expert software version 11.1.2.0 using response surface methodology (RSM) for central composite randomized design (CCRD) with quadratic model. Analysis of variance (ANOVA) was used to evaluate the significance of each parameter and the interactions between parameters on tillage quality. Comparisons among treatment means, were conducted using F-test at p = 0.01, 0.03 and 0.001 level.

3. RESULTS AND DISCUSSION

3.1 Effect of operating parameters on tillage quality

The effect of operating parameters (forward speed, rotary speed and depth) of J shape rotavator blades on tillage quality (SMMD) at maintainable soil physical properties (cone index, bulk density and moisture content) in laboratory under soil bin condition were observed and analyzed in this experiment. The results are shown in the Table1 and Fig-2.

As shown in Table 1 and Fig-2, J shape rotavator blade with different operating parameters (forward speed, rotary speed and depth of operation) have significant effect on soil tillage quality (SMMD). This means the soil mean mass diameters (SMMD) resulting from the analysis of soil aggregate sizes obtained after tillage operation using J shape rotavator blade was statistically different. However, in the same experiment with different operating parameters; at experiment 11, maximum SMMD (3.68 mm) was observed at (2 km/h, 232 rpm, 100 mm) and minimum SMMD (1.11 mm) in experiment 8 and 10 at (1.5 km/h, 500 rpm, 80 mm) and (2.5 km/h, 300 rpm, 80 mm) respectively.

Table -1: Effect of tillage quality of J shape rotavator blade on operating parameters by maintaining soil physical properties.

Cone Index (80±12kPa), Bulk density (1.20±1g/cm3), Moisture content (15±1%), Medium textured soil				
Run	**Forward Speed (Km/h)**	**Rotary Speed (rpm)**	**Depth of operation (mm)**	**Smmd (mm)**
1	2**	400***	100****	2.312*
2	2**	568***	100****	1.628*
3	1.5**	300***	120****	2.78*
4	2.5**	500***	120****	2.78*
5	2**	400***	134****	3.10*
6	2**	400***	100****	2.312*
7	2**	400***	100****	2.312*
8	1.5**	500***	80****	1.11*
9	1.5**	300***	80****	1.85*
10	2.5**	300***	80****	1.11*

11	2**	232***	100****	3.68*
12	1.2**	400***	100****	1.28*
13	2**	400***	66****	1.526*
14	2.5**	500***	80****	1.85*
15	2**	400***	100****	2.312*
16	2.8**	400***	100****	2.99*
17	2.5**	300***	120****	2.78*
18	2**	400***	100****	2.312*
19	2**	400***	100****	2.312*
20	1.5**	500***	120****	1.67*

*, **, ***, **** - significant at 1, 3, 1, 0.1 % level respectively, Run - series of running experiments.

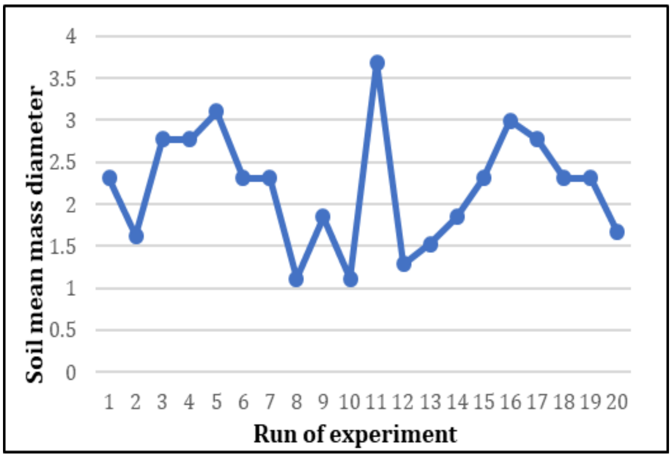

Fig -2: Effect of operating parameters (forward speed, rotary speed and depth) on soil mean mass diameter

3.2 Effect of tillage depth on soil mean mass diameter (SMMD)

As shown in Table 1, each tilling depth affected significantly on SMMD resulted from J shape rotavator blade. This means the soil mean mass diameters resulting from the analysis of soil aggregate sizes after tillage operation using J shape rotavator blade were statistically different. However, in the same depth of operation it found that, Maximum SMMD (3.68 mm) was observed at 100 mm depth in experiment 11, minimum SMMD (1.11 mm) was observed at 80 mm depth of operation in experiment 8 and 10 respectively.

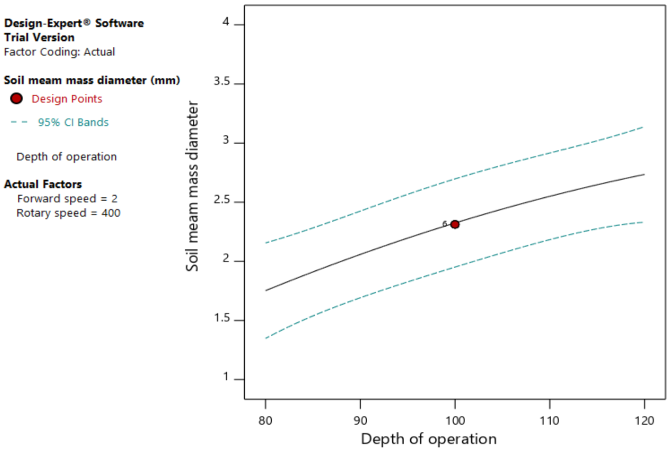

Fig -3: Effect of tillage depth on soil mean mass diameter

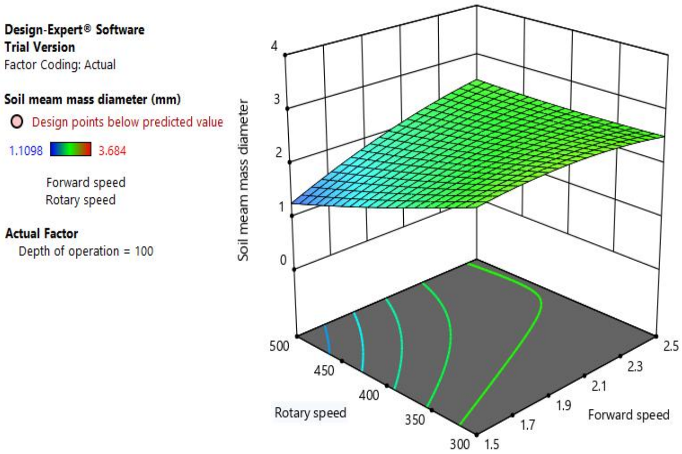

Fig -4: Interaction effect of rotary and forward speed on soil mean mass diameter at average tillage depth

Results show that, the value of SMMD for J shape rotavator blade during tillage operation increased with increase tillage depth at optimum conditions (Fig.3). However, in (Fig.4), it shows the interaction effect of rotary and forward speed by controlling average tillage depth. SMMD increased by increase forward speed and decrease by increase rotary speed at an average tillage depth of 100 mm.

3.3 Effect of forward speed on soil mean mass diameter (SMMD)

As shown in Table 1, each forward speed affected significantly on SMMD resulted from J shape rotavator blade. This means the soil mean mass diameters resulting from the analysis of soil aggregate sizes after tillage operation using J shape rotavator blade were statistically different. However, in the same forward speed it found that, Maximum SMMD (3.68 mm) was observed at 2 km/h in experiment 11, minimum SMMD (1.11 mm) was observed at 1.5 km/h and 2.5 km/h of forward speed in experiment 8 and 10 respectively.

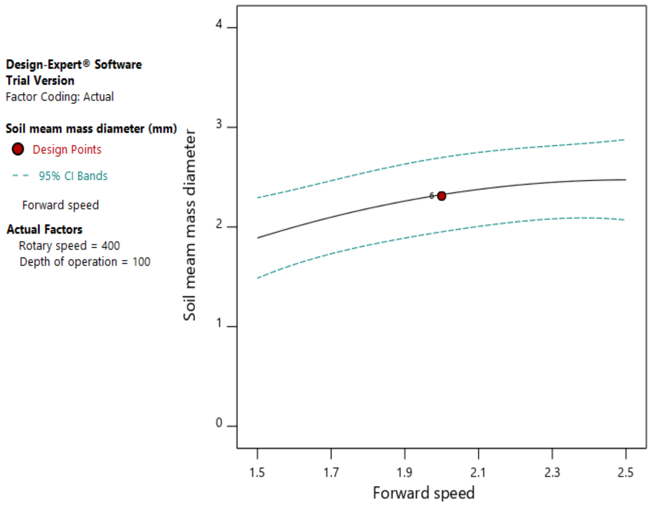

Fig -5: Effect of forward speed on soil mean mass diameter

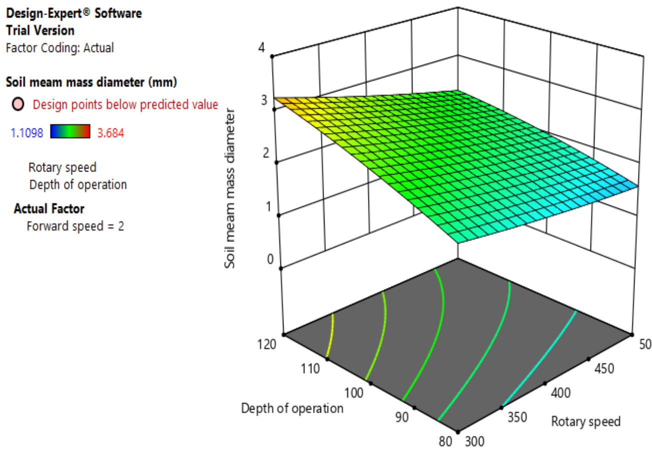

Fig -6: Interaction effect of tillage depth and rotary speed on soil mean mass diameter at average forward speed.

Results show that, the value of SMMD for J shape rotavator blade during tillage operation increased with increase forward speed at optimum conditions (Fig.5). However, in (Fig.6), it shows the interaction effect of tillage depth and rotary speed by controlling average forward speed. SMMD increased by increase tillage depth and decrease by increase rotary speed at an average forward speed of 2 km/h.

3.3 Effect of rotary speed on soil mean mass diameter (SMMD)

As shown in Table 1, each rotary speed affected significantly on SMMD resulted from J shape rotavator blade. This means the soil mean mass diameters resulting from the analysis of soil aggregate sizes after tillage operation using J shape rotavator blade were statistically different. However, in the same rotary speed it found that, Maximum SMMD (3.68 mm) was observed at 232 rpm in experiment 11, minimum SMMD (1.11 mm) was observed at 500 and 300 rpm of rotary speed in experiment 8 and 10 respectively.

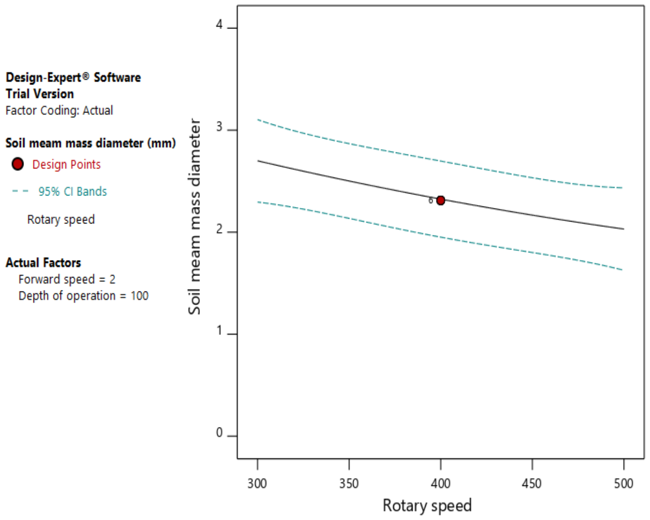

Fig -7: Effect of rotary speed on soil mean mass diameter

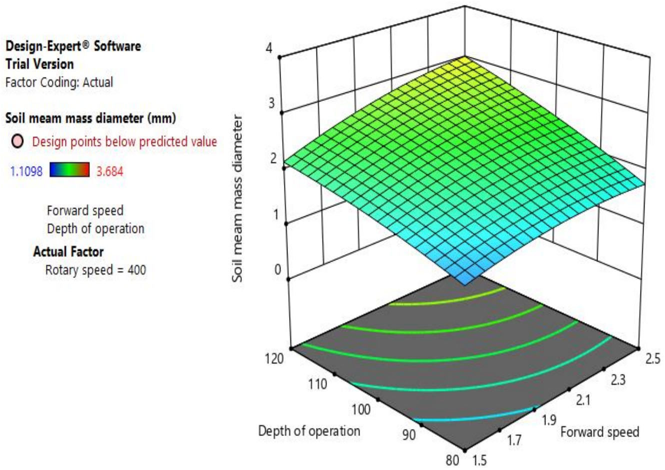

Fig -8: Interaction effect of tillage depth and forward speed on soil mean mass diameter at average rotary speed.

Results show that, the value of SMMD for J shape rotavator blade during tillage operation decreased with increase rotary speed at optimum conditions (Fig.7). However, in (Fig.8), it shows the interaction effect of tillage depth and forward speed by controlling average rotary speed. SMMD increased by increase forward speed and decrease by decrease tillage depth at average rotary speed of 400 rpm. Similar results were reported for operating parameters on rotary tiller blade (Rajesh et all., 2018).

4. CONCLUSION

From the study it is concluded that. J shape rotavator blade interaction on operating parameters in a controlled physical property under soil bin laboratory condition for medium textured soil was observed and analyzed in terms of tillage quality. It has been found out that, to get better performance, J shape rotavator blade should be operated at about 100 mm tillage depth, 400 rpm rotary speed and with the forward speed of 2 km/h. Among the operating parameters, there was considerable significant difference in soil tillage quality, rotary speed was significantly higher than forward speed and tillage depth (Table-1), therefore to attain the desirable soil tilling quality it required to increase rotary speed while tillage depth and forward speed required to decrease to optimum condition.

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