RESEARCH PAPER International Journal of Agricultural Engineering | Volume 11 | Issue 1 | April, 2018 | 73-78
e ISSN–0976–7223 ■ Visit us : *www.researchjournal.co.in* ■ DOI: 10.15740/HAS/IJAE/11.1/73-78

Effect of rotary tiller blades on soil disintegration

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Received : 17.01.2018; **Revised :** 11.02.2018; **Accepted :** 20.02.2018

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■ **ABSTRACT :** Weeding between the crop rows is the most important practice to enhance the yield. The blade shape, forward speed and rotary speed are the key parameters come to decision for pulverizing soil condition. Thus, this study was aimed to determine the furrow formation characteristics of two blades used in rotary weeder. The experiments were carried out in indoor laboratory soil bin condition. The moisture content of the clay soil was 12 to 13 per cent and penetration resistance was 590 kPa. The rotary shaft was attached with a flange with four blades and the rotor diameter was 250 mm. The highest furrow backfill of 76.26 per cent was reported by the straight blade at lower forward speed. The furrow backfill has decreased with increase in both forward speed and rotary speed of two blades. Maximum ratio of soil breaking of 92.86 per cent was obtained at a rotary speed of 300 rpm by the straight blade. Ratio of soil breaking has decreased with increase in forward speed and increased with increase in rotary speed. Based on the results rotary weeding technique with straight blade was found to be effective.

■ **KEY WORDS :** Rotary blade, Rotary weeder, Soil bin, Furrow backfill, Soil breaking

■ **HOW TO CITE THIS PAPER :** Rajesh, A.N., Shridar, B. and Jesudas, D. Manohar (2018). Effect of rotary tiller blades on soil disintegration. *Internat. J. Agric. Engg.*, **11**(1) : 73-78, **DOI: 10.15740/HAS/IJAE/11.1/73-78.**

Weed control is one of the most limiting factors faced by the farmers in crop production. To avoid the yield losses, weeds must be avoided from the field throughout the season. Weed control without damaging the soil and environment can be realized only through mechanical weeding. The potential yield loss due to weeds can be as high as about 65 per cent depending upon the crop, degree of weed infestation, weed species and management practices. Maximum yield loss reported for rice under direct seeded was 64 per cent followed by ground nut 63.3 per cent, cotton 60.4 per cent and minimum for potato is 29 per cent (Yaduraju *et al.*, 2006)

In India, mechanized weeding during the crop growing stage is not practiced well especially weeding between the rows. The main difficulty to practice this is, the most of the crops are grown in narrow spaced rows. The prime importance of the inter row weeding is to loosen the soil in shallow depth to cut or cover the weeds. This leads the soil to less bulk to increase the aeration and infiltration. To obtain a soil cover thick enough to provide effective weed control, about 0.02 m of soil covering is necessary (Terpstra and Kouwenhoven, 1981).

The shape of the blade can affect the soil cutting, throwing pattern and the profile of the furrow (Chertkiattipol and Niyamapa, 2008). Mohler (2001) observed that the mould board ploughs invert the soil, and consequently tend to bury growing weeds with relatively less crumbling. Field cultivators invert the soil to a lesser extent than moldboard ploughs, but still tend to bury the weeds. Rotary tillers chop up weeds and crop residue, and mix them into the soil profile to the depth of penetration. Disks tend to cut the weeds whereas rotary tillers tear, but the effect on the plants was often similar

The objective of this study was to determine furrow formation characteristics of two different blades for developing a rotary weeder for inter row cultivation in dry land. The effect of blade shape, forward speed and rotary speed of furrow backfill and ratio of soil breaking were investigated.

METHODOLOGY

The blade geometries namely straight and C-shaped that are used in power weeder and available in the local market were selected for this study.

Soil bin system and soil preparation :

The experiments were conducted in an indoor rectangle soil bin of 42 m length, 2.2 m width and 0.75 m depth of clay soil (Fig. A). The experiments were conducted in clay soil, a typical extreme soil condition (Niyamapa *et al.*,1994 and Salokhe *et al.,* 1993). For all the experiments, the soil bed was prepared with a moisture content in the range of 12 per cent to 14 per cent (Gorkhali, 1985) and cone index of 575 to 590 kPa (Simens *et al.*,1965; Luth and Wismer, 1971; Wells and Theeswan, 1978 and Lisowski *et al.*,2014) were maintained. The soil in the experimental bin was tilled three times with a tractor operated rotavator at a depth of 80 mm. The tilled soil was levelled with leveller attached with the bottom of the soil bin car. Before tilling, the soil was sprinkled with water in to a desired depth and left for two days to maintain the soil moisture content. The tilled soil was compacted with a tractor operated roller of width 1500 mm, diameter of 150 mm and weight of 340 kg to reach a targeted bulk density (Reddy, 2010). Before conducting the experiments, the soil samples were collected from the upper 50 mm layer of soil randomly with a core cutter to measure the soil moisture content and bulk density. The moisture content was determined by oven drying the soil at 105 ºC for 24h (Lisowski *et al.,* 2016). The cone index was measured by a type B cone penetrometer with a cone base area of 129 mm², cone base diameter of 12.83 mm and apex angle of 30º (Terpstra and Kouwenhoven, 1981).

Fig. A : Indoor rectangular soil bin, (1) Loading car, (2) Clay soil and (3) Sandy soil

Test rig for rotary blades:

To obtain the variable rotary speeds, an electric motor of 3 phase 5 hp drives the hydraulic motor having discharge of 32 cc rev^{-1} and maximum torque of 380 Nm powered by a variable speed frequency controller. A single row rotary weeding unit was fabricated for the laboratory studies. The right hand and left hand blades were fixed in the flange as facing opposite sides rotated in forward direction of rotation to cut the soil. Four blades were fitted in a square flange at an angular spacing of about 90º (Lee *et al.,* 2003). The diameter of the flange with rotary blades was 250 mm Fig. B.

Fig. B : Experimental setup (1) Loading car, (2) Main frame, (3) Depth control wheel, (4) Rotary tool carrier, (5), Rotary blade and (6), Hydraulic motor

Three forward speeds of 1.0, 1.5 and 2.0 km h^{-1} and three rotor speeds of 200, 250 and 300 rpm (Matsou, 1961;Patnaik, 1982; Baloch *et al.*, 1986 and Shibusawa, 1993) were selected for this study. For tilled soils an average of 10 to 15 per cent of seeds deposited at a depth of 5 cm and 30 to 40 per cent at a depth of 50 to 100 mm, respectively (Nichols *et al*., 2015). Hence, the depth of operation selected as 50 mm to cut the germinated weeds and width of operation was 100 mm.

Data collection and processing:

After the testing the blades at different operational conditions the experimental plots were left uncovered for one day for drying and hardening the soil clods. Soil samples were collected from 300 mm long furrow section. To mark the section boundary two steel sheets were inserted across the soil. The soil clods thrown into the sides of the furrow were removed carefully before collecting the loose soil remaining in the furrow.

Furrow backfill :

Furrow backfill is the proportion of soil mass retained within the furrow after tillage. After marking the boundaries with the plates the soil retained in the furrow was collected and sieved with a 20 mm sieve. The samples were oven dried at 105 °C for 24 hours to get the dry mass. The furrow volume was calculated by using a sand replacement method (Matin *et al.*, 2014) with well graded sand of 1 mm particle size and a bulk density of 1.433 g cm^{-3}. After collecting the soil sample the cleaned furrow was lined with a thin plastic cover of 75µm thick and filled by the sand. The furrow backfill was proposed by Matin *et al.* (2014) was calculated using the eq. (1):

$$FB = \frac{W}{V\rho} x100 \quad ......(1)$$

where,

FB: Furrow backfill, per cent

W: Total dry mass of soil remaining in the furrow, kg

V: Volume of the tilled furrow, m^3

ρ : Bulk density of the untilled soil kg m^{-1}.

Ratio of soil breaking :

Soil failure pattern and the corresponding reactions will be changed for different soil types, tool parameters and different operating conditions (Makanga *et al.*, 1996). Rotary tilling is practiced to produce well aggregated soils with a large number of unsaturated pores to improve the soil aeration and weed killing. Ratio of soil breakage as proposed by Lee *et al.* (2003) and Matin *et al.* (2014) was calculated using the eq. (2):

$$SB = \frac{Wf}{(Wc + Wf)} x100 \quad .....(2)$$

where,

SB: Ratio of soil breakage, per cent

Wf: Dry mass of fine clods, smaller than 20 mm, kg

Wc: Dry mass of fine clods, 20 mm and larger, kg.

Experimental method:

The data collected as the effect of two type of blades *viz.*, straight and C-shaped, at three forward speed of operation *viz.*, 1, 1.5 and 2 km h^{-1}, three rotational speeds *viz.*, 200, 250 and 300 rpm on furrow backfill and ratio of soil breakup were analysed using Factorial Completely Randomized Factorial Design (FCRD) with three replications. The statistical software AGRES was used to analyze the data.

■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Furrow backfill :

The forward speed of operation and rotary speed had significant effect ($p<0.01$) on furrow backfill (Fig. 1). Increase in forward speed for a particular rotary speed decreased the furrow backfill. The maximum furrow backfill of 76.26 per cent was attained at lower forward speed and rotary speeds of 1 km h^{-1} and 200 rpm, respectively. Both blades showed a similar trend of reduction in furrow backfill with an increase in rotary speed from 200 to 300 rpm. The straight blade has no lifting or carrying of soil and the tendency of loose soil to move laterally was intercepted by the following blade and directed back into the furrow, which was observed in the previous studies carried out by Matin *et al.*, 2014. For straight blade furrow backfill decreased by 16 per cent to 22 per cent with increase in forward speed from 1to 2 km h^{-1}. There was a decrease of 14 to 33 per cent with increase in rotary speed from 200 to 300 rpm correspondingly.

The C- shape blade produced maximum furrow backfill of 60.69 per cent at forward speed of 1 km h^{-1} and rotary speed of 200 rpm (Fig. 2). This may be due to the conventional blades threw the soil higher and further at higher speed as reported by Matin *et al*. (2014). Furrow backfill decreased by 19 per cent to 32 per cent for the forward speed variation from 1 to 2 km h^{-1}. There was a decrease of 26 to 45 per cent in furrow backfill with the increase rotary speed from 200 to 300.

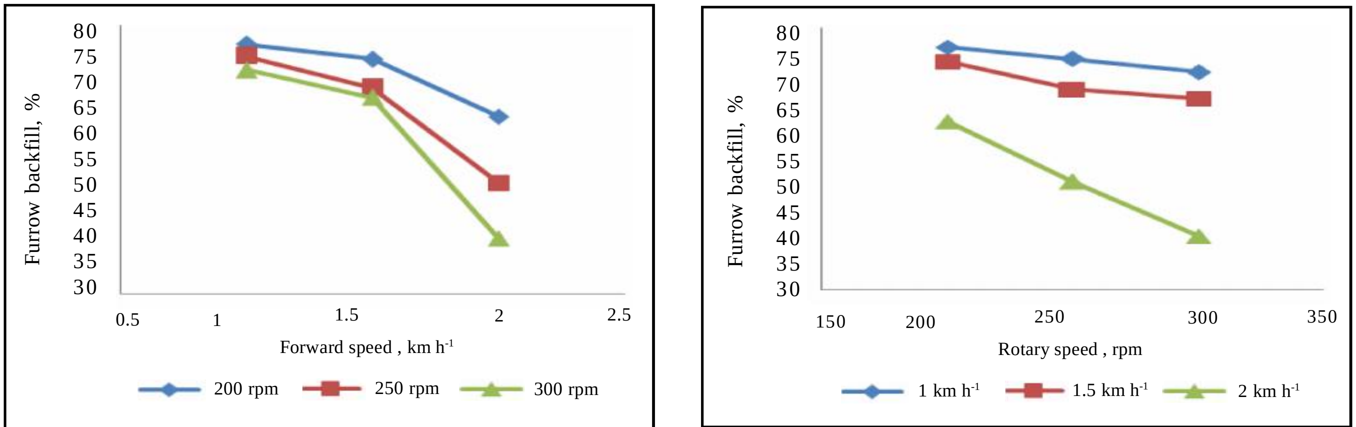

Fig. 1 : Effect of forward speed and rotary speed on furrow backfill for straight blade

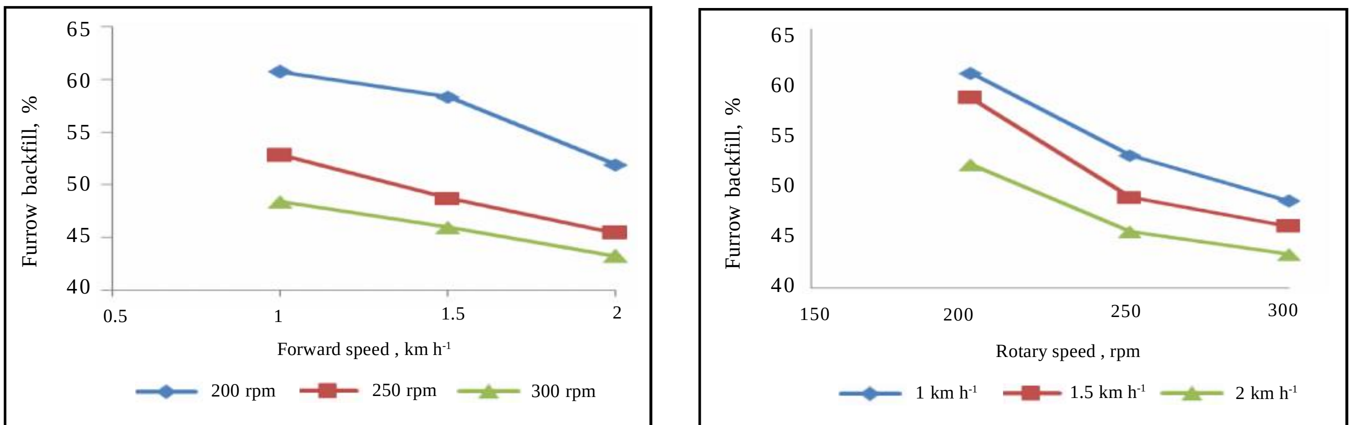

Fig. 2 : Effect of forward speed and rotary speed on furrow backfill for C-shaped blade

Ratio of soil breaking:

Ratio of soil breaking was significantly affected ($P<0.01$)by blade geometry, forward speed and rotary speed. Ratio of soil breaking has decreased with the increase in forward speed. The maximum ratio of soil breaking of 37.50 per cent was obtained for the straight blade when the blade operated at a forward speed of 1km h^{-1} and rotary speed of 300 rpm (Fig.3). This result is supported by the findings of Beeny and Khoo (1970) and Chamen *et al*. (1979) who observed that the higher rotor speed gives more soil breakage due to shorter bite length. For the straight blade increase in forward speed from 1 to 1.5 kmh^{-1} ratio of soil breaking has decreased by 15 per cent and it was 14 per cent and 27 per cent for 1.5 to 2 kmh^{-1} and 1 to 2 kmh^{-1}, respectively. At the lower rotary speeds of the blades, straight blade created few lateral cracks during its entry into the soil and during the exit of the furrow it pushed out the some soil and created few clods was outlined in previous studies (Matin *et al.*, 2014).

Whereas the C-shaped blade reported the maximum ratio of soil breaking of 70 per cent was at a forward speed of 1km h^{-1} and rotary speed of 300 rpm (Fig. 4). The maximum ratio of soil breaking attained for various forward speeds of 1.5 and 2 km h^{-1} was 68.42 per cent and 63.16 per cent, respectively. When the rotary speed increased from 200 to 300 rpm there was an increase in ratio of soil breaking. The lowest ratio of soil breaking of 14.29 per cent was obtained for a rotary speed of 200 rpm at 2 km h^{-1}. It was observed that when the forward speed varied from 1 to 1.5 kmh^{-1}, ratio of soil breaking has decreased by 10 per cent and it was 22 per cent and 29 per cent for 1.5 to 2 kmh^{-1} and 1 to 2 kmh^{-1} correspondingly.

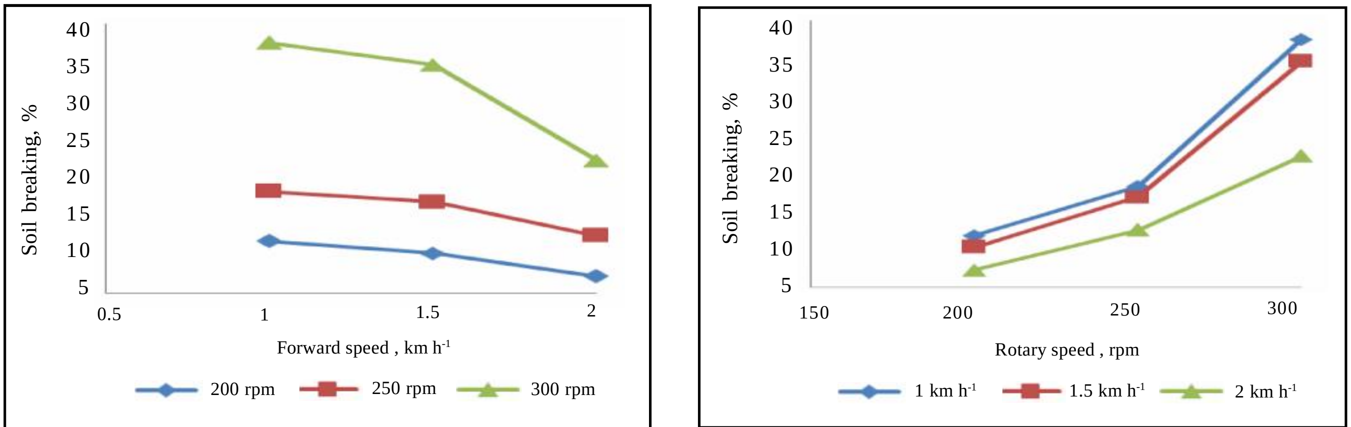

Fig. 3 : Effect of forward speed and rotary speed on ratio of soil breaking for straight blade

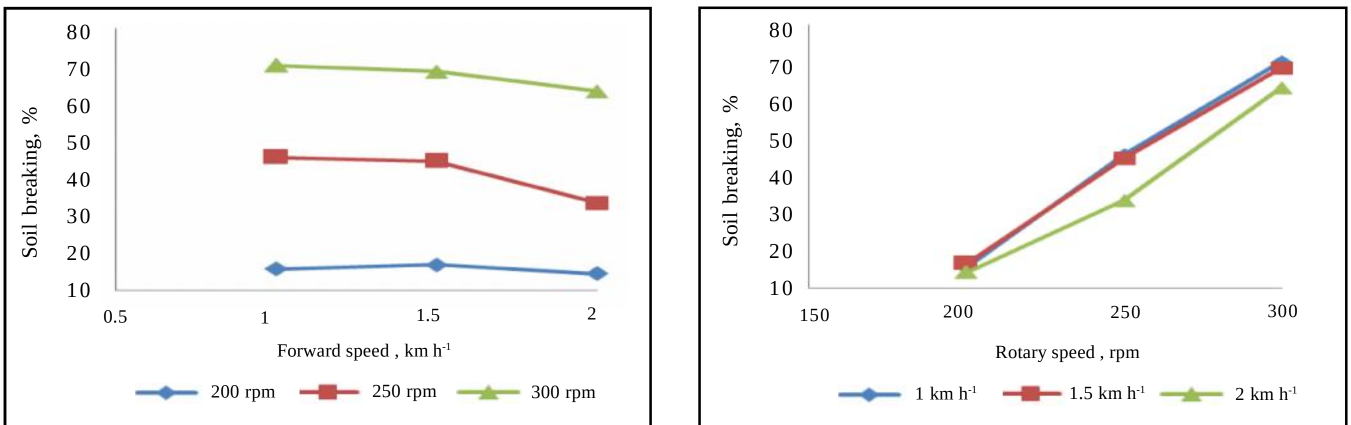

Fig. 4 : Effect of forward speed and rotary speed on ratio of soil breaking for C-shaped blade

Conclusion:

From the study it is concluded that the straight blade geometry attained the maximum furrow backfill of 76.26 per cent at a forward speed of 1km h^{-1} and rotary speed of 200 rpm due to the less scattering of soil from the furrow. C- Shaped blade produced 60.69 per cent of furrow back fill for the corresponding levels of parameters. Among the treatments there was considerable significant difference in furrow backfill and ratio of soil breaking. Ratio of soil breakage of straight blade was significantly higher than the C- Shaped blade. Straight blade have 34 per cent higher furrow back fill than C- Shaped blade at 1 km h^{-1} and 29 per cent for ratio of soil breaking for the same speed level.

Acknowledgement:

The research work was supported by University Grants Commission, Rajiv Gandhi National Fellowship, New Delhi. The authors are grateful to Agricultural Machinery Research Centre, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University Coimbatore for providing facilities to carry out the research

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