Indian Journal of Weed Science **51**(3): 284–289, 2019

Print ISSN 0253-8040 Online ISSN 0974-8164

Development of non-powered self-propelling vertical axis inter row rotary weeder

Satya Prakash Kumar*, V.K. Tewari[1], C.R. Chethan[2], C.R. Mehta, Brajesh Nare[3], A.K. Chandel[4]

ICAR – Central Institute of Agricultural Engineering, Bhopal, Madhya Pradesh 462 038, India

[1]Indian Institute of Technology, Kharagpur, West Bengal 721 302, India

[2]ICAR – Directorate of Weed Research, Jabalpur, Madhya Pradesh 482 004, India

[3]ICAR – Central Potato Research Station, Jalandhar, Punjab 144 003, India

[4]Biological Systems Engineering, Washington State University, Pullman, 99164, WA, USA

**Email: satyaprakashkumar27@gmail.com*

Article information

DOI: 10.5958/0974-8164.2019.00060.1

Type of article: Research article

Received : 17 July 2019
Revised : 8 September 2019
Accepted : 10 September 2019

Key words

Cutting blade

Field capacity

Rotary wheel

Vertical axis rotary

Weeding efficiency

ABSTRACT

Maize is the third most important cereal crop in India and is most susceptible to weed management practices. Weeding is one of the costliest and laborious operations in crop cultivation. Most of the existing weeders are of horizontal type and very less work done on vertical axis rotary weeders and energy aspects of the weeding units. A study was under taken to develop non-powered self-propelling vertical axis rotary weeder to eliminate the external powering unit, which provides the energy to cut the weeds and soil. The developed weeder was tested in maize crop at 2 and 4 cm of operational depth and 15 and 30 DAS of crop growth stages. The developed weeder performed very well at all the crop growth stages and obtained a weeding efficiency of 65 to 70% with 1.98 to 5.88% of plant damage. The highest cob yield of 12.9 t/ha was recorded weeding at 15 DAS followed by 30 DAS. However a care must be taken and a safety zone *i.e.* a gap of 7-10 cm between machine edges to the tip of plant leaves should be maintained to avoid the plant damage. At operational depth of 2 cm the draft force required to pull the weeding unit was 6.3 kgf and obtained field capacity was 0.08 ha/h, which was higher when weeder was operated at 4 cm of operational depth.

INTRODUCTION

The advanced agricultural practices such as precised application of agricultural inputs, timeliness of operation, proper selection of cropping systems *etc*. are need of the hour to enhance higher crop yields. Further, the man power involved, man-machine relationship, human drudgery and energy aspects in crop cultivation are other such parameters responsible to achieve energy efficient crop cultivation (Chethan and Krishnan 2017, Chethan *et al.* 2018a and b). Maize is the third most important cereal crop in India and is most susceptible to weed management practices The maize crop was heavy doses of fertilizers during its growth period to enhance the crop growth. This heavy doses was lead severe infestation of the weeds (Naidu and Murthy 2014, Mynavathi *et al.* 2015), thus crop yield was reduced drastically. Weeds malign the crop yield by absorption of nutrients and resources mainly supplied for optimum growth of crops (Slaughter *et al.* 2008). Weed management is a strategy that makes a desired plant population successful in a crop field by utilizing knowledge of the ecology of the weeds (Ghersa *et al.* 2000). But, weeding is one of the costliest and laborious operations in crop cultivation and needs effective and timely management of weeds. There are several existing methods of controlling weeds such as manual, chemical, biological or mechanical. The earliest and smoothest method of all is the manual weed control, where farmers used their hands to uproot weeds, which is then advanced to hand tools such as khurpi, hand-hoe etc. (Tewari *et al.* 1993). Herbicides are one of the crucial factors in a worldwide increase in cereal production. Clearly the farmer using herbicides in maize production is saving money but due to demand of chemical free food, there is a need of efficient weeding technique to cut and mix the weeds in maize field.

The weed control is a frequent process and so the labor requirement in manual weeding method is very expensive, time consuming and difficult (Weide *et al.* 2008). The introduction of chemical weed control methods has relieved the weeding operation from these undesirable factors (Tewari *et al.* 2014, Chandel *et al.* 2018). However, due to herbicide-resistant weeds, environmental impact of herbicides and increasing demand for non-toxic foods, investigations of alternative methods of weed control has gained popularity.

Mechanical inter-row weeders such as inter-row cultivators, rotary cultivators and basket weeders are available in the market (Cloutier *et al.* 2007, Tewari and Chethan 2018). The performance of weeding tools is determined by their specific draft, energy requirements and the quality of works. Generally, cultivator and rotary tiller are used for weeding operation in Indian agriculture. Cultivator cut, dig the weeds and left over the surface and rotary tiller cut the weeds and also mix in soil. Rotary tiller (horizontal plough) rotates in vertical plane and impact on ground during weeding operation causes of increase soil resistance *i.e.* hard layer pan in line of crops row that may be prevent the leaching of water and nutrient to root zone of crops and effects the yield (Azadbhakt *et al.* 2014). The vertical rotary plough never creates hard pan at soil surface like horizontal rotary and gives better quality of soil. Soil resistance in vertical axis rotary plough is less and tilling quality is much more than horizontal one (Makange *et al.* 2015). Keeping the above sited problem, a non-powered self-propelling vertical axis inter row rotary weeder was developed which rotates in vertical axis to uproot, cut, mixes and cover the weeds in soil.

MATERIALS AND METHODS

Weeder development

A non-powered self-propelling vertical axis rotary weeder was developed at research laboratory of AgFE department, Indian Institute of Technology, Kharagpur. So many researchers have developed and evaluated the powered vertical axis rotary weeder for weeding under inter row cropping conditions, but very little have concentrated on the energy requirement aspect of the weeder (Makange and Tiwari 2015, Jakasania *et al.* 2017, Batista *et al.* 2018). A new concept of vertical axis rotary weeder, which is self-propelled by itself due to the motion of the tractor was developed. To cut the soil in vertical direction, a special type of trapezoidal shaped blades having the dimensions of 5×2×9 cm (a×b×h) was developed. These blades were made from boron steel having a hardness of 40-50 HRC. Total nine numbers of cutting blades were fixed to a specially developed rotary wheel unit and set at cutting angle of 45^0 to the direction of travel (**Figure 1**). At this cutting angle, the blades offers a complete coverage of the crops row. Later, the weeding unit was attached to a frame in vertical axis through bearing system and mounted on tractor with three point hitch system. The used bearing in an attachment offers no frictional resistance to the rotating unit. Further, there was no any other means of external power was provided to the rotary weeding unit to propel and cut the soil. During weeding operation, the cutting blades are engaged with soil and soil offers a frictional resistance to the cutting blades. When tractor starts to move in linear motion, the force acting in longitudinal direction caused by tractor movement generates a centrifugal force on rotary weeding unit, due to which the unit tends to self propel in perpendicular direction i.e.in vertical axis and cut the weeds and soil. Thus, requirement of external power to rotate the weeding unit was eliminated.

Field preparation

The testing of the developed weeders was conducted at the research farms. The field was prepared with help of tillage implement and well levelled. The soil samples were collected from the experimental sites to find the soil texture and test was conducted based on the USDA soil classification system (Azadbakht *et al.* 2014). It was found that soil texture was sandy loam. Before testing of the developed weeder in field condition it was prior tested in the soil-bin under different soil cone index varied from 300-500 kPa with rotary cutting blade depth from 2 to 6 cm.

Crop management and weeder testing

After soil-bin testing of the developed weeder, the different parameters were optimized such as number of blades, cutting angle, cutting depth, safety zone between plant stem to edge of rotary weeder, ground clearance of the weeding unit *etc* (**Table 1**). The hybrid maize crop was selected to test the developed weeder. A seed rate of 20 kg/ha was maintained and sown at 60 and 30 cm of row-to-row and plant-to-plant spacing during *Rabi*. A fertilizer dose of 150 kg of N, 70 kg of P and 70 kg of K was provided to the crops. Two stages of crop growth were selected such as crop at 15 and 30 days after sowing (DAS) to the test the weeder. It was ensured that, the weeder was passing at the centre of adjacent crop rows by maintaining a safety zone of 7 cm. Further, the weeder was also tested at two different depths such as 2 cm and 4 cm. The developed weeder was operated at forward speed of 1.6 and 2.25 km/h for 2 and 4 cm depth of operations

Table 1. Parameters optimized to develop vertical axis rotary weeder

Parameters		Optimized value
Number of blades		9
Width of cutting within a row, cm		46
Cutting angle of blade, degrees		45^0
Cutting depth, cm		2-4
Safety zone for weeder pass, cm		7
Ground clearance of weeding unit, cm	at 15 DAS	40
	at 30 DAS	90
Speed of operation, km/h		1.60
		2.25

respectively (speeds obtained in tractor at different gears). The different parameters such as, draft force required to weed out, field capacity, field efficiency, weeding efficiency, plant damage and cob yield was recorded based on the observations noted and also by using the formulas.

The draft force required by the implement was measured by using two tractor system, in which a load cell dynamometer was placed between the tractors and reading was noted (RNAM 1983, Smith *et al.* 1994). The power required to weeding, theoretical and actual field capacity (TFC and AFC), field and weeding efficiency (FE and WE) and plant damage (PD) were calculated based on the equations mentioned below (Smith *et al.* 1994, Chethan, 2013, Chethan and Krishnan 2017).

The power required to weeding at different speeds was calculated as follows.

$$Power\ (hp) = \frac{Draft\ (kg) \times Speed\ (kmh^{-1})}{270} \tag{1}$$

The field efficiency is calculated as follows.

$$FE\ (\%) = \frac{TFC}{AFC} \tag{2}$$

where,

$$TFC\ (hah^{-1}) = \frac{Mean\ working\ width\ (cm) \times Mean\ speed\ (ms^{-1})}{10000} \times 36 \tag{3}$$

and

$$AFC\ (hah^{-1}) = \frac{Total\ area\ cultivated\ (ha)}{Total\ workingtime\ (h)} \tag{4}$$

The plant damage is calculated as follows.

$$PD\ (\%) = \frac{P-Q}{P} \times 100 \tag{5}$$

Where, P is the number of plants in a 10 m crop row length before weeding and Q is the number of plants in a 10 m crop row length after weeding.

Statistical analysis

The weed data were transformed into square root transformation($(\sqrt{x+0.5})$) to avoid the high variances of the values during statistical analysis. The study was conducted in split plot design and replicated thrice. The data was analyzed in ICAR-IASRI, New Delhi online statistical portal.

RESULTS AND DISCUSSION

The vertical axis rotary weeder was developed (**Figure 2**) and tested in the laboratory condition *i.e.* under soil bin at different soil cone index and operational depth. The operational environment at the field condition was recreated in soil bin to test the developed weeder for its prior settings and to optimize the operational parameters. A range of operational depth, blade cutting angle and cone index was selected under soil-bin test. The developed weeder was optimized for blade cutting angle of 45^0, operational depth of 2 to 4 cm and cone index of 300 to 500 kPa. At these parameters, the developed weeding unit was achieved a maximum area of coverage, which results

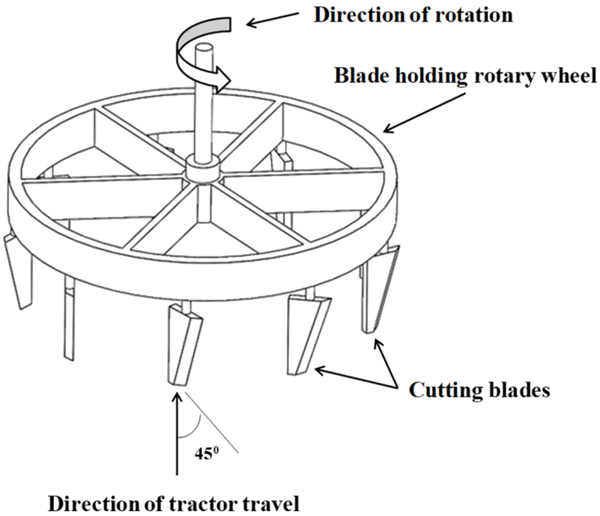

Figure 1. Working direction of the blades and rotary unit

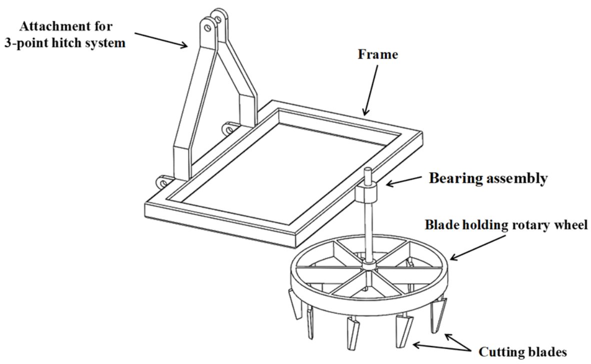

Figure 2. Developed vertical axis non-powered-self-propelling rotary weeding unit

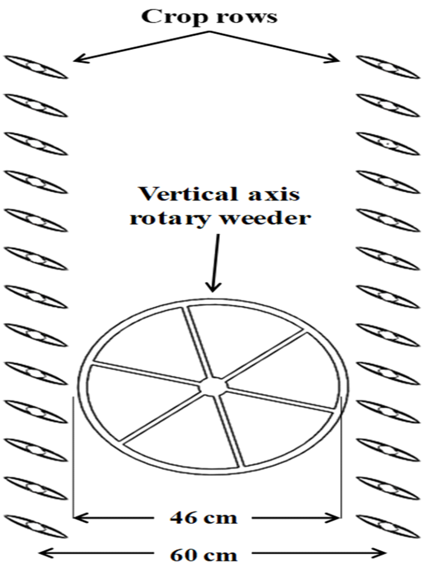

Figure 3. Schematic diagram of working operation of vertical axis rotary weeder

higher weeding efficiency. Therefore the same operational parameters were maintained during field testing at different crop growth stages. The rotary wheel and cutting blades adjustment was made such that, the weeding unit was able to achieve a working width of 46 cm for effective weed control. The developed weeder was operated in between the crops and maintained the position that, the unit must pass at the centre portion, so that, a safety zone of 7 cm *i.e.* distance between the edge of weeder rotary unit to the crop stem, was maintained to avoid damage to the crop stem and to the crop roots. The operational view of the developed weeder along with the safety zone is shown in **Figure 3**.

As discussed in the above portion, the developed weeder was tested at the maize field. Two crop growth stages *i.e.* 15 DAS and 30 DAS was selected for the testing. Five plant samples randomly taken within the test field to measure the crop height. The measured crop height at 15 DAS was up to 30 cm and at 30 DAS was up to 75 cm (**Figure 4**). At these stages the crop development was such that, a proper ground clearance was maintained in tractor and in the weeder attachment, thus crop damage due to dragging of lower portion of tractor body as well as the weeding unit was avoided. A proper lubrication in bearing system was done to ensure the free movement of the rotary unit, so that, the weeding unit will work efficiently. The cone index of the soil was measured and it was obtained in the range of 318 to 423 kPa by using a digital cone penetrometer. The measured cone index was within the optimized range, thus the weeder was tested.

The measured and calculated parameters such as the plant damage, weeding efficiency, field efficiency, actual field capacity, draft required to pull

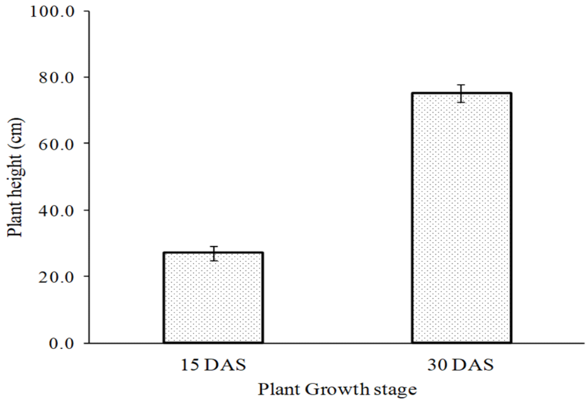

Figure 4. Height of maize crop at different growth stages

the weeder and cob yield recorded were statistically analyzed and given in the **Table 2**. The operation of developed weeder at different crop stages has a significant effect on plant damage, field capacity and efficiency and in cob yield. Whereas the operational depth significantly affects the field capacity and efficiency, weeding efficiency and draft force required to weed out the plants. However, on dependent parameter *i.e.* field capacity and field efficiency both operational depth and crop growth stage have significant effect. The highest plant damage of 5.88 % was observed in crop growth stage at 30 DAS (**Figure 5**). This highest value was achieved due to clogging of non-uniformly developed maize crop leaves to the weeding unit and restriction of the weeder movement within the row. This restricted movement of the weeding unit directly affects the time required to cover a unit area. Thus, a reduced actual field capacity and field efficiency was seen at 30 DAS compared to 15 DAS (**Figure 6**). Further, the plant damaged caused by the weeder at 30 DAS also affected the cob yield *i.e.* 12.20 t/ha, which was 5.4% lesser than the treatments at 15 DAS, but the draft force and power required to weeding was unaffected. In treatments having the 15 DAS offers minimal restriction to the weeder movement, therefore a very least plant damage value of 1.98% and higher cob yield of 12.9 t/ha was observed. This effect can be clearly seen in the figure.7. Therefore a proper ground clearance and care must be taken while weeding at higher growth stages of the crop. Always ensure a proper gap of 7 to 10 cm between machine body to the tip of the plant leaves to avoid plant damage.

As like in different crop growth stage treatments the similar type of effects are also in depth of operation treatments. As the operation depth was increased from 2 cm to 4 cm the forward speed of the tractor was reduced to overcome the problem of missing the weeds, abrupt throwing of the soil towards outside and longer tilling pitch. Even though

Table 2. ANOVA table for different parameters

Treatment	Plant damage (%)	Weeding efficiency (%)	Field efficiency (%)	Actual field capacity (ha/h)	Draft (kg force)	Cob yield (t/ha)
Operational depth (cm)						
2	3.92	73.87	80.03	0.08	6.30	12.63
4	3.94	64.89	57.97	0.04	7.89	12.47
LSD (p=0.05)	NS	1.20	11.91	0.01	0.08	NS
Crop growth stage (DAS)						
15	1.98	65.98	72.89	0.07	7.11	12.90
30	5.88	69.18	65.11	0.06	7.08	12.20
LSD (p=0.05)	3.86	NS	2.92	0.00	NS	0.30

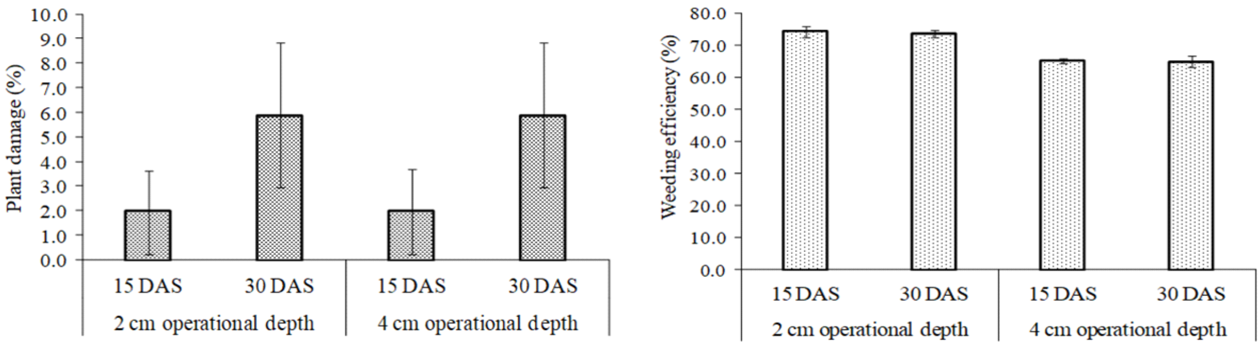

Figure 5. Plant damage and weeding efficiency obtained by weeder at different crop growth stages

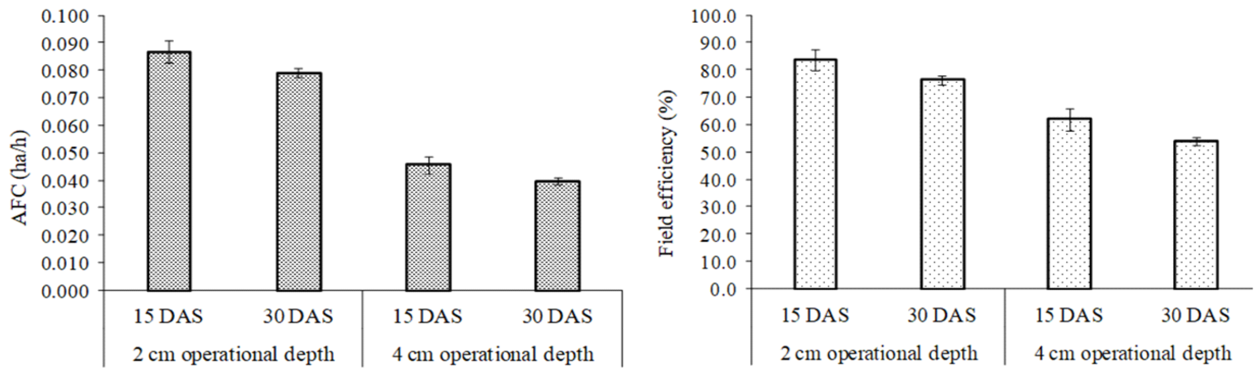

Figure 6. Actual field capacity and field efficiency of the weeder at different crop growth stages

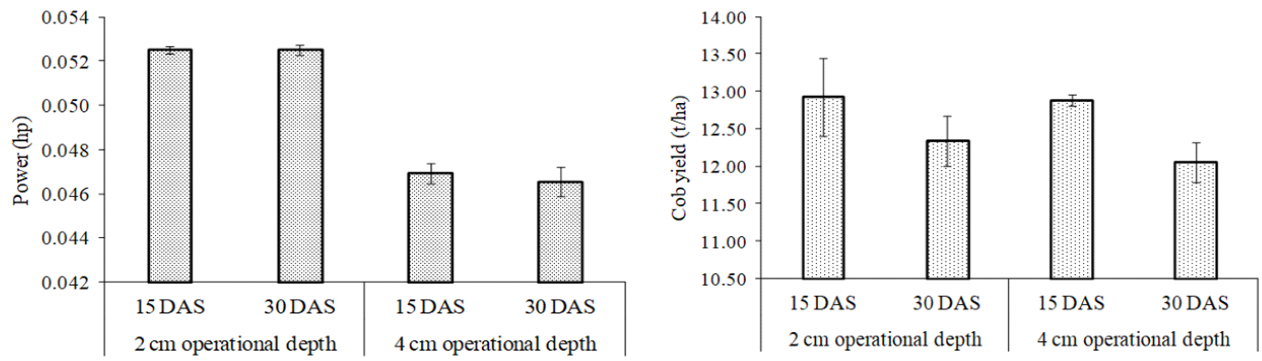

Figure 7. Power required by the weeder and cob yield obtained at different growth stages

the speed of operation reduced, some of the weed plants were escaped due to longer tilling pitch compared to the operational depth of 2 cm (speed of operation was 2.25 km/h). Thus, it affected the weeding efficiency, field efficiency and capacity, but does not have any effect on cob yield (**Figure 5**, **6** and **7**). It is obvious that, when the speed of operation reduces the field capacity will also automatically get reduced. The obtained values are 0.04 ha/h and 57.8% respectively for field capacity and field efficiency at operational depth of 4 cm, which was 27 to 50% lesser compared to the values obtained in treatments at operational depth of 2 cm. Further, the treatments having the operational depth of 2 cm achieved the higher weeding efficiency of 73.9% with higher field efficiency of 80%, higher field capacity of 0.08 ha/h and minimal draft requirement of 6.3 kg force. However, the plant damage was not significantly affected and obtained a value of around 3.9%. To obtain higher weeding efficiency with minimum plant damage and draft force requirement an operation depth of 2 cm can be adopted.

Non-powered self-propelling vertical axis rotary weeders can be developed without incurring an extra cost required for the external power unit to perform propelling and weeding operation. The developed weeders will match to all type of tractors ranging from lower horse power to higher horse power as it only requires draft force, that to in lower range. Therefore, with some modification according to the cropping conditions, the developed weeders can be used in different crops.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Indian Institute of technology, Kharagpur and PC, AICRP-FIM for providing financial and technical support to conduct this study.

REFERENCES

Azadbakht M, Azadbakht B, Galogah RJ, Kiapei A and Jafari H. 2014. Soil properties after plowing with horizontal and vertical axis rotavator *International Journal of Environmental and Ecological Engineering* **8**(1): 61–65.

Batista N, Melicio Rand Mendes V. 2018. Darrieus-type vertical axis rotary-wings with a new design approach grounded in double-multiple streamtube performance prediction model. *AIMS Energy* **6**(5): 673–694.

Biswas S, Debnath S, Saha A, and Biswas B. 2018. Weed management in maize system in new alluvial zone of West Bengal, India. *International Journal of Current Microbiology and Applied Sciences* **7**(4): 1344–1350.

Chandel AK, Tewari VK, Kumar SP, Nare B and Agarwal A. 2018. On-the-go position sensing and controller predicated contact-type weed eradicator. *Current Science* **114**(7): 1485–1494.

Chethan CR. 2013. *Development and Ergonomic Evaluation of Manually Operated Weeders Based on Push-pull Force Requirement*. Un-published M.Sc. thesis, CAE&RI, TNAU, Coimbatore, India.

Chethan CR, Subhash Chander and Satya Prakash Kumar. 2018a. Dynamic Strength based Dryland Weeders – Ergonomic and Performance Evaluation. *Indian Journal of Weed Science* **50**(4): 382–387.

Chethan CR, Singh PK, Dubey RP, Singhariya C and Choudhary VK. 2018b. Herbicide application in agriculture: nozzle selection and effective application. *Indian Farming* **68**(12): 28–30.

Chethan CR and Anantha Krishnan D. 2017. Dynamic push–pull strength data generation for agricultural workers to develop manual dryland weeders. *Current Science* **113**(8): 1601–1605.

Cloutier D C, Weide RYVD, Peruzzi A and Leblanc M L. 2007. Mechanical weed management. pp. 111–134. In: *Non-Chemical Weed Management*. CAB International.

Ghersa C, Benech ARL, Satorre EH, Martinez GMA. 2000. Advances in weed management strategies. *Field Crops Research* **67**(2): 95–104.

Jakasania RG, Vadher AL and Kathiria RK. 2017. Performance evaluation of vertical rotary plough. *Journal of Scientific Research & Reports* **13**(6): 1–7.

Jat RK, Gopar R and Gupta R. 2012. Conservation agricultural in maize-wheat cropping systems of eastern India: Weed dynamics and system productivity. In: *Extended Summaries Vol. 3, 3rd International Agronomy Congress*, New Delhi, India.

Kumar S, Rana SS, Chande N and Angiras NN. 2012. Management of hardy weeds in maize under mid-hill conditions of Himachal Pradesh. *Indian Journal of Weed Science* **44**(1): 11–17.

Makange NR and Tiwari VK. 2015. Effect of horizontal and vertical axis rotavators on soil physical properties and energy requirement. *Trends in Biosciences* **8**(12): 3225–3234.

Mynavathi VS, Prabhakaran NK and Chinnusamy C. 2015. Manually-operated weeders for time saving and weed control in irrigated maize. *Indian Journal of Weed Science* **47**(1): 98–100.

Naidu VSGR and Murthy TGK. 2014. Crop – weed interactions under climate change. *Indian Journal of Weed Science* **46**(1): 61–65.

Regional Network for Agricultural Machinery. 1983. *RNAM Test Codes and Procedures for Farm Machinery*. Los Banos, Philippines. 297p.

Singh AK, Parihar CM, Jat SL, Singh B and Sharma S. 2015. Weed management strategies in maize (*Zea mays*): Effect on weed dynamics, productivity and economies of maize-wheat (Triticum aestivum) cropping system in IndoGangatic plains. *Indian Journal of Agricultural Sciences* **85**(1): 87–92.

Slaughter D, Giles D and Downey D. 2008. Autonomous robotic weed control systems. A review, *Computers and Electronics in Agriculture* **61**(1): 63–78.

Smith DW, Sims BG and O'Neil DH. 1994. Testing and evaluation of agricultural machinery and equipment - principles and practices. *FAO Agricultural Services Bulletin 110.* FAO of United Nation, Rome. 48p.

Tewari VK, Kumar A, Nare B, Satya Prakash, Tyagi A. 2014. Microcontroller based roller contact type herbicide applicator for weed control under row crops. *Computers and Electronics in Agriculture* **104**: 40–45.

Tewari VK, Datta RK and Murthy ASR. 1993. Field performance of weeding blades of a manually operated push-pull weeder. *Journal of Agricultural Engineering Research* **55**:129–141.

Tewari VK and Chethan CR. 2018. Mechanization in weed management: Global review. pp. 215–237. In: *Fifty Years of Weed Research in India* (Eds. Sushilkumar and Mishra JS). Indian Society of Weed Science, India.

Tripathi AK, Tewari AN and Prasad A. 2005. Integrated weed management in rainy season maize (Zea mays L.) in Central Uttar Pradesh. *Indian Journal of Weed Science* **37**(3&4): 269–270.

Weide RYV D, Bleeker PO, Achten VTJM, Lotz LAP, Fogelberg F and Melander B. 2008. Innovation in mechanical weed control in crop rows. *Weed Research* **48**(3): 215–224.