S.V. Shamkuwar *et al*, International Journal of Advances in Agricultural Science and Technology,
Vol.6 Issue.12, December-2019, pg. 1-22 **ISSN: 2348-1358**
Impact Factor: 6.057
NAAS Rating: 3.77

A CRITICAL STUDY ON WEED CONTROL TECHNIQUES

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ABSTRACT: Weed is a major problem in crop production, affecting the crop yield as well as the quality of harvested produce. Weeds compete with the main crop for soil nutrients (NPK) of worth Rs 5,000 crores per year in India. The value of total crop losses due to weeds is around Rs. 10,000 crores (Rao, 2000). Weed control is one of the most difficult tasks in crop production agriculture that accounts for a considerable share of the cost involved in agricultural production. There are many methods for weed management, but out of those methods, chemical methods are the most popular. These methods are hazardous for the environment as well as for human health. To ensure food security and sustainable development of agriculture, it is critically important to develop chemical and pollution-free agricultural products. This study has been carried out to know the different weed controlling techniques used by the different researchers to be adapted in agricultural work.

Keywords: Weed, crop, management, chemical and agricultural.

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INTRODUCTION

The different types of weeding techniques are in practice such as chemical, mechanical, etc. Although herbicides can provide effective weed management, there also deteriorated to the environment by pollution.

Chemical Weed Control

In chemical weed control method was done by the use of herbicides. Selective herbicides kill certain targets while leaving the desired crop relatively unharmed. These act by interfering with the growth of the weed and are often based on plant hormones. Contact herbicides destroy only plant tissue that contacts the herbicide. Systemic herbicides are foliar-applied and move through the plant where they destroy a greater amount of tissue.

Singh and Tsuchiya (1982) found the highest net return chemical weed control technique; the highest net return was obtained with two weeding done at 15 and 30 DAS of rice. When herbicide application was combined with hand weeding, the highest net return was obtained with thiobencarb at 2 kg/ha followed by butachlor at 2 kg/ha and thiobencarb at 1.5 kg/ha each combined with one hand weeding at 45 DAS.

Biswas *et al*. (1984) reported that advanced countries had mostly switched over to chemical control. The use of chemicals for weed control was quite low in India. However, a large number of herbicides were now available to control different types of weeds in rice crop. The reasons for the limited use of herbicides in India had high-cost herbicides, lack of knowledge on the available herbicides and most of the actions. Effective chemical control weed required different herbicides and management practices in various systems of rice cultivation.

Tewari (1987) developed a weeder cum herbicide application machine design a ground wheel made of MS with 40 cm diameter having MS rod spokes, and a wheel guide extended rearward and fixed to the main platform made of angle iron having slots to attach different weeding blades. The unit could be used both as a mechanical weeder and herbicide applicator. To enable the machine work as a weeder it could be conveniently attached with various weeding range blades-flat inclined, flat inclined with serrated edges, four-time double and the improved double blade. The applicator mechanism consisted of a feed tank, dripping mechanism, and application mechanism. The herbicides consumption was 100 to 200 l/ha. The mechanical weeder required 8 to 12 man-days/ha.

Cheema *et al.* (2005) studied field trial in cotton crop with chemical, mechanical and manual methods for controlling weeds. Weed biomass was significantly reduced from 75 to 95 % in all the weed control treatments and seed cotton yield was increased by 46 to 61 %.

Channappagoudar and Biradar (2007) conducted experiments in soybean and red gram intercropping systems with fives pre-emergence herbicides and in combination with cultural practices inter cultivation and hand weeding along with the weed-free plot and unweeded plot to control the weed. A significant reduction in the weed biomass was noticed by all the herbicides application plot over the unweeded control plot. The plant height of soybean was significantly highest in weed-free plots.

Khan *et al.* (2009) reported that potato plant growth in chemically treated weeding plots with manual weeding was significantly improved as compared to the growth in the unweeded plot. It was observed that all the weed management plots produced significantly improved marketable yield as compared to unweeded plots.

Nalini *et al.* (2011) conducted experiments in cotton crop to evaluate weed management practices with chemical weed control application of pre-emergence and early post-emergence herbicides, cultural practices mulching with straw and hand weeding once in twice and weed-free situation hand weeding 10 times of for unwanted weed control. A combination of manual and chemical weeding gave a higher seed cotton yield of 58 % compared to manual weeing treatment.

Hussain *et al.* (2013) conducted experiments in potato crop with a total of nine treatments including eight herbicides and an unweeded plot for comparison. The results revealed that all the herbicides had a significant effect on weed density and also on the tuber yield of potato. Herbicidal treatment significant reduced the weed population as compared to control treatments, with 104 weed/m^2. All the treatment resulted in more than 80 % mortality of weed that infested the field before the application of the herbicides. No crop injury was observed in any of the herbicides used in the experiment. The herbicides combination gave the highest potato tuber yield 15,910 kg/ha, which was 36% higher than the without herbicides treatment.

Chauhan *et al*. (2014) suggested that, in Asian countries, weed in rice, like unwanted plants like weed cultivated with rice, these plants produce damaged grains reduced rice yield from 16% to 74%.

Ali and Abdulai (2014) suggested that weed control was the biggest challenge to conservation agriculture adoption. Weed ecology and management was different in conservation agriculture than in conventional agriculture. In conservation agriculture, weeds expression, seed bank status, distribution, dispersal mechanisms, diversification, growing patterns, and competition trends were complex and differ from conventional systems. It was due to reduced tillage of the soil and the flora that thrives in conservation agriculture. Reduced tillage systems affect the efficacy of herbicides and mechanical weed control measures. So, it was an important task to find out the differences and to formulate new management options.

Mechanical Weed Control

To control the weed mechanically many types of weeders have been developed depending upon power source, soil type, and crops. These weeders generally cut, bury or uproot weeds. The different types of weeding tools to be attached to the weeder have developed by many researchers.

Datta *et al.* (1974) said that weeding traditionally carried out with indigenous hand tools. Involving considerable time and labours. A mechanical device to remove the weeds from agricultural land is known as weeder. A weeder may be manual or animal drawn and tractor mounted or power operated. Considering the importance of the problem of weeding, the Regional Network for Agricultural Machinery (RNAM) of ECAP initiated a sub network activity on testing, evaluation and adoption of weeders during 1978.

Biswas *et al.* (1984) reported that the control of weeds was the oldest method of weed control. It received that the less scientific attention as compared to the other methods of weed control. The tools and implements for mechanical weed control were mostly used. Mechanical control of weeds involves use weeders operated by humans, animal-drawn or tractor drawn weeders, self-propelled weeders or power weeders.

Quadri (2010) reported that the mechanical weeder was made of two implements attachment i.e. the primary cutting edge which was in front to loose soil above and the secondary cutting edge which was behind to do cutting and lifting of weeds. The weeding efficiency manually operated weeder on loamy soil was 81.14%, clay soil was 93.75% and sandy soil was 94.29%. The overall machine field efficiency was 98.67%.

Veerangouda *et al.* (2010) reported that weeding usually performed by manually with traditional hand tools Khurpi in upright bending posture inducing back pain for majority of labour and required considerable time. It was very costly and many times, availability of the required number of labour during peak season of the year was a problem. In India, diverse farm mechanization scenario prevails in the country due to varied size of the farm holdings and socio-economic disparities. At present, small capacity power weeder was available in market whose field capacity normally 0.07 ha/hr.

Bhuvaneswari and Chinnusamy (2010) conducted the field experiments in non-chemical weed management methods for organically grown maize and sunflower cropping system. Twin wheel hoe weeding at 20 DAS + hand weeding at 40 DAS registered that the higher weed control efficiency in maize 92.4 and 93.5 % and in sunflower 91.9 and 94.7 % during 2007-2008 and 2008-2009, respectively. Higher yield was obtained with twin wheel hoe weeding at 20 DAS + hand weeding at 40 DAS in maize 58.2 and 61.8 % and sunflower 49.4 and 61.1 % over unweeded control during first and second year, respectively.

Chaudhary *et al.* (2011) reported that hand hoeing gave higher weed control, 95.77 and 98.12 % of broad and narrow leave weeds, respectively and produced lowest weed dry matter 15.46g/m^{2}in lentils crop. Significantly highest grain yield of 1,519.56 kg/ha was obtained by hand hoeing with an increase in yield of 117.46 percent over weeding. The weed gave lowest yield 698.78 kg/ha. The highest additional return of Rs. 41,247/ha with a cost benefit ratio (CBR) of 1:5.16 was obtained by hand hoeing twice.

Shiru (2011) design that, a push-pull type of mechanical manual weeder consisting designed and fabricated. The weeder consists of main frame, handle, soil cutter (wedge), spikes, wheel bearing, bicycle chain and sprockets. It was quite simple, effective. Tests result showed a weeding index of 74.53%, efficiency of cutting blades of 88% and field capacity of

0.02 ha/h. Small scale farmers can take advantage of the improved weeder to control weeds on their farms.

Muhammad and Attanda (2012) developed a hand push mechanical weeder that consisted of two set of cone rotor blades, adjustable main frame and a float. The weeder, of effective field capacity of 0.357 ha/h had 64.87 N draft and overall width and depth of cut of 180 mm and 20 mm respectively. With a single run of cut in between the rows on the field at a soil moisture content of 40.8%, the optimum weeding efficiency was 84.5% while weeding efficiency at 10.5% soil moisture content was 15%. Consequently, the highest plant damage of 8.33% was recorded at the 10.5% soil moisture content and the 0.058hp power was required by a single person to push the prototype weeder.

Gongotchame *et al.*, (2014) conducted study on participatory approaches to examine the suitability of six mechanical weeders ring hoe, fixed-spike weeder, curved spike floating weeder, twisted-spike floating weeder, straight-spike weeder and two row spike-and-blade. Weeder has compared in order of preference with weed management practices. The ring hoe had the highest rank with 97 % farmers preference in the fields of non-ponded water and relatively.

Merfield (2016) said that weeder working in sandy soils performed well in clay soils at optimum soil moisture contents, but performed poorly at other moisture contents. This variability in weeder performance might lead to requirements of different weeders for clay soils at high and low moisture contents. Stones are another complicating factor for mechanical weeding, leading to damage or reduced effectiveness of some weeders, while others may be mostly unaffected.

To control the weeds mechanically many types of weeder having different weeding tools has developed, depending upon power source, crop and soil, etc. These weeders generally uproot the weeds. The classifications of these weeding toolsare given below:

Manual Weeder

Khan and Diesto (1987) reported a push type cono-weeder which uproots and buries weeds in a single pass without requiring a back forth movement, especially suitable for rice.

Manual weeding of rice in one hectare requires on an average of 120 man hrs. The cono weeder was about twice as for as to operate as that conventional rotary weeder.

Kumar *et al.* (2013) reported that two types of manual weeder cono-weeder and Mandava weeder for shallow water conditions were selected and evaluated for different age group of workers 25 to 30, 30 to 35, and 35 to 40 years at different day timings T1 = 8.00 to 11.00 AM, T2 = 12.00 to 2.00 PM, and T3 = 4.00 to 6.00 PM. The weeding operations by different age group of workers at different working hours showed that the heart rates corresponding to cono-weeder and Mandava weeder were 154.54 beats/min and 140.17 beats/min, respectively. Oxygen consumption rate were 1.76 l/min and 1.47 l/min respectively. Working during 12:00 to 2:00 PM with both weeders developed maximum heart rate and oxygen consumption rate as compared to 8:00 to 11:00 AM and 4:00 to 6:00 PM. The study also revealed that, agricultural workers of 25 to 30 years age group developed maximum working heart rate and oxygen consumption rate, during weeding operations, which were higher than the age groups of 30 to 35 years and 35 to 40 years.

Animal Drawn Weeder

To control the weed animal drawn technique many type of weeder been has developed depending upon the power source, soil type, and crop. These weeder generally cut, burry uproot weeds.

Beeny and Khoo (1970) developed three blade shapes with different radius of curvature C-shape, I-shape and L-shape. They reduced the cutting force by reducing ratio of blade surface to contact with soil to volume and the soil cut by the blade. They also compared to the performance of optimized rotary blades are the basis of specific work. The specific work requirement of the L-shape blade was found comparatively higher than the other two types of blades in operating conditions.

Lukyanov (1978) studied that the parameters of rotary tiller blades are studied with the view of decreasing energy requirements. The design of the cutting blades mounting on the rotor should guarantee free movement in the soil being cut loose. It was found that decrease in the speed, angle of cutting length, and the forward face of the blade reduced energy requirements.

Sakai (1978) conducted that rotary tools of rotary tiller was equivalent to share of moldboard plough and use of rational shape of rotary tool is indispensable for effective tillage. It was found that on the rotary tiller the external soil forces, i.e. driving forward force and lifting up force were presumed to be affected by the radial suction force of the blade. There was caused by the shape of the scoop surface of the blade and by the knife factor which depended upon the shape of knife edge.

Yadav and Anderson (1980) conducted study on the serrated blade for hoe and harrow, bullock drawn blade cum tine hoe for weeding and intercultural operations in dry land farming. The serrated blade of different size may be fitted in to the traditional blade hoe or blade harrow (bakhar). The serrated blades easily penetrated into the soil and help in moisture conservation.

Murthy and Gowda (1996) evaluated that the performance of a bullock drawn blade hoe for 3 different approach angles 120°, 130° and 140°to determine the most effective angle with respect to implement draught, soil moisture conservation, weeding efficiency and crop of finger millet yield under dry land conditions. The overall performance of blade hoe was best with an approach angle of 140° with respect to the formation of ridges and furrows, soil moisture conservation and yield but the draft was significantly higher 19.5kg.

Biswas *et al.* (1999) reported that animal drawn weeder worked between crop row spacing, the weeds left over a long rows might be removed manually. The straight blades in traditional hoes tend to remove weeds up to the working width of the blades. However, due to clogging of the straight edges, the output was adversely affected. So, they concluded there was need to study and use improved blades.

Balachand (2006) designed and developed an animal drawn weeder considering the functional requirements and its required strength to bear soil forces acting on it. The performance of animal weeder having 3 types of blade viz. straight blade, curved blade, and sweep blade was compared with the Ambika paddy weeder and hand weeding. Weeding by Animal drawn weeder with sweep blade resulted in higher field capacity 0.0759 ha/h, field efficiency 73.87% and performance index 738.75 then the other two blades.

Self-Propelled Weeder

Adams and Furlong (1959) suggested that rotavator mostly available with working width of 1.20 to 1.80m, which was suitable for tractors having 45hp and above. Further, rotavator may have ‘L’ shape, ‘C’ shape, ‘J’ shape, hook tines and straight knife blades to suit various operating conditions. The L-shaped of blades gives better penetration than hook-shaped or pick type blades in trashy conditions.

Kinzel *et al.* (1981) said that the rotavator blade had ‘L’ shape, ‘C’ shape, ‘J’ shape, hook tines and straight knife blades to suit various Indian conditions. But the, L-shaped blades were used mostly in Indian rotavator. There were lot of work has been done on this subject particularly to develop blade kinematics, modeling of blade, matrix equations etc. and also the motion of the blade of rotary tiller.

Yatsuk and Panov (1982) reported the miniature rototillers for soil working. Rototillers with small cutting width can also be used for light cultivation and weeding the space between the rows of some crops. Manual weeder with a flexible drive shaft and a portable engine earned on the shoulders was one of the types of miniature rototillers. The depth of soil working was regulated by the forward speed of the tiller the lower the speed, the greater the depth of soil working. Miniature tillers were widely used in England, Japan and Italy.

Singh and Agarwal (1988) developed a front mounted power tiller on the farm attached cutter blade to accomplish cutting in small time period. Bearings inside a hollow shaft were used to support a cutting blade rotating in horizontal plane and power transmission was done using a bevel gear set and V-belt. On testing it was found that only 16 man-hour were required to accomplish the cutting of one ha but power of the engine was underutilized thus making wastage of energy.

Thakur and Godwin (1990) observed that peak resultant force occurred after penetration of the blade tip at 10° to15°, the blade traversed a circular trajectory in quasistatic condition.

Gupta and Pandey (1991) evaluated the performance of two rotary tyne, a spiral cutting edge and a straight cutting edge in a soil bin. The study was conducted at four different rotor speeds with two modes of operations. The linear speed and working depth were kept constant at 1.33 km/h and 100 mm respectively. The performance criteria were specific energy requirement and pudding index. The result revealed that the spiral edge tyne gave about 9.31 % higher performance index than the straight edge tyne under wet land condition.

Gupta and Visvanathan (1993) suggested a mathematical model for a rotary blade in saturated lateritic sandy clay loam soil. The energy requirement for rotary tiller consisted of 0.34 to 0.59% for cutting soil slice, 30.5 to 72.4% for throwing out soil slices, 0.96 to 2.45% for overcoming soil-metal friction, 0.62 to 0.99% for soil-soil friction and for the ideal power 23.1 to 64.6%. The mathematical model was developed to predict the energy requirement for the combined effect on a disc plow and a rotary blade in clay soil suitable for wet rice cultivation in Malaysia.

Tewari *et al.* (1993) concluded that the overall performance of a straight flat blade was the best. The field efficiency was highest, physical damage to crop was the least and weed removal per unit area was the greatest. The average power required by push-pull weeder was 21.3 W.

Singh (1996) found that tools of the ‘L’ and ‘C’ shapes consumed minimum specific energy in comparison to other conventional rotary tillage tools. The proper design of the interrelated cutting and the clearance angles of rotary tiller blades is essential for the efficient operation. The effective cutting angle was increased from some minimum value of the power requirements of the tiller and the amount of soil pulverizing, throwing and mixing were increased.

Pullen and Cowell (1997) assessed the ability of different mechanical weeding mechanisms viz.harrow, sweep, ducks foot, rotary powered hoe, ground driven rotary hoe and rotary brush devices to control weeds at different growth stages in the uncropped area between crop rows and at different forward speeds. The powered rotary hoe worked well at all growth stages at 5 km/h but its performance declined as well as working speed was increased .The brush weeder did not do as well as some mechanisms because its inability to penetrate and the low speed of the rotor . The ground driven rotary weeder worked well at all speeds but was less able to crop with established plant growth.

Panwar (1999) reported that designed and developed a lightweight, low horsepower engine operated weeder cum seeder for weeding of row crops and single row seeding of different crops. The machine was powered with 1.5hp petrol start kerosene run engine. The common chassis was designed for reduced rolling resistance and adequate traction ability. The engine power was transmitted to 280 rpm ground wheel through a specially designed reduction gear box and chain and sprocket system. For weeding operation, three types of tools such as hoe blade, sweep and L-blade were attached at the rear of the machine. The weeding tool can be selected based on density of the weed and requirement of the operator. The field capacity of the machine ranged between 0.5-0.6 ha/day for 8 working hours per day. The average fuel consumption was observed in the range of 300-350 l/h.

Manian *et al.* (2004) developed a unit consisting of an inter-cultivation equipment fitted to standard tractor drawn ridger. Three sweep types blade of 45 cm width were affixed to ridger frame with 120° approach angle and 15° lift angle for accomplishing weeding operation in between standing rows of crops. The unit was evaluated for its performance with available weeders and conventional method of weeding. Weeding efficiency of the tractor-drawn weeding-cum earthing up implement having V shaped sweep bottom was 60.24 %. The saving in the cost of operation and time with bullock drawn junior hoe, self-propelled power weeder having weeding efficiency 78.7%, 79.8%, 68.7% and tractor drawn weeding-cum earthing up implement having weeding efficiency 96.5%, 96.6 %, when compared to manual weeding efficiency 98.9 %, respectively.

Narang and Tiwari (2005) reported the performance of a light weight power tiller. It was work in black soil having sand, silt and clay content of 12.6 %, 32.7 % and 54.7 %, respectively. The average moisture content and bulk density of soil were 17.41% (db) and1.48 g/cm^3. The weeding efficiency, effective field capacity, forward speed of operation, rotary speed, depth of tiller, mean heart rate and operating duration of 15 min overall discomfort rating on the10 point VAD (visual analog discomfort) scale of power tiller were 65.47%, 76.26 %, 0.15ha/h, 0.16 ha/h, 2.77 km/h, 3.13km/h, 89 rpm, 72 rpm, 50 mm, 47 mm, 123.2 beats/min, 129 beats/min and2.6, 3.75, respectively.

Tajuddin (2006) designed, developed and tested an engine operated weeder with 2.2 kW (3hp) petrol started kerosene run engine. The rated speed of 3300 rpm at load was reduced to 60 rev/min of ground wheel by belt pulley and sprocket chain mechanism. A sweep type weeding blade was designed for structural strength. The effective field capacity 0.10 ha/h, fuel consumption rate 0.60 to 0.75 l/h, depth of operation 37 mm, 35 mm, 39 mm, field efficiency 85.71%, weeding efficiency 85.85%, initial cost of weeder 20,000/-Rs cost of operation 580/ha were found.

Cloutier *et al.* (2007) stated that mechanical weed control was generally widespread and used by farmers who do not use herbicides the recommendations always come to control weed during the early crop stages because of limited tractor and cultivator ground clearance and machine contact with the plant and potentially damage the crop foliage at later growth stages.

Padole (2007) compared the performance of rotary power weeder and bullock drawn blade hoe. Rotary power weeder comprised of engine, gearbox, clutch, main frame, depth control wheel, V shaped sweep, cutter wheels, handle, controls and transportation wheels. It worked better than bullock drawn blade hoe in respect of working depth 5.67cm 16.67 percent more, effective field capacity 0.14 ha/h 40 percent more, and field efficiency percent, which was 34.11 % more than that of bullock drawn blade hoe. The cost of operation was found to be 798.46/ha compare to 894.87/ ha by bullock drawn blade hoe. Hence, it was more economical and effective than bullock drawn blade hoe as it saved 10.77% weeding cost and reducedplant damage up to 54.23 %, and achieved weeding efficiency up to 92.76 %.

Manuwa *et al.* (2009) designed and tested a petrol engine powered mechanical weeder for row crop at Federal University of Technology, Nigeria. The main component of weeder was 5hp internal combustion petrol engine, 21 transmission unit, three sets of weeding blades main frame and ground wheel. The length, width and height of weeder were 0.85, 0.32, 0.65 m, respectively. The cutting blade width was 0.24 m which rotated at 800 rpm. The field test was conducted in moist soil condition, determined weeding efficiency as 95% with effective weeding capacity of 0.053ha/h and fuel consumption of 0.7 l/h. The production cost of weeder was US$ 285 in 2007.

Nkakini *et al.* (2010) designed and fabricated a rotor-weeder powered with 1.4 hp petrol engine and compared the field performance with the traditional manual hand hoe. The weeder consists of main frame, handle, rotary blades, shaft, sprocket and chain, chassis, cutting depth, rear cutting depth adjuster, wooden engine seating, engine and ground wheel. Theoretical field capacity of the rotor-weeder was 0.47 ha/h with an effective field capacity 0.34 ha/h which was approximately twenty times that of manual weeding. The performance index was 1,700 and fuel consumption was 3.2 l/day. Weeding efficiency of rotor weeder was 71 % for removing shallow-rooted weeds.

Zareiforoush *et al.* (2010) presented a new theoretical approach to design main tillage components of rotary tillers. The rotary tiller shaft, it was revealed that in addition to the torsional moment, the flexural moment was also effective on the system and safety. It was known that in designing a rotary tiller, blades are subjected to fracture by incoming stresses. The optimum value of rotor diameter considering the values of maximum tangent force was about 39.4 mm.

Srinivas *et al.* (2010) reported that weeding efficiency and performance index of ‘L’ shape blade rotary weeder was more effective weeding than the ‘C’ type rotary weeder and sweep type weeder. The increased soil contact and soil inversion capacity of rotary weeder contributed to its higher weeding efficiency. The ‘L’ shape weeding blade churning the soil by uprooting weeds was recommend for inter row crop weeding with shallow depth of soil.

Rathod *et al.* (2010) developed a tractor drawn inter-row weeder with consideration of soil, machine and crop parameters. The test was performed with forward velocity of 1.1, 1.2, 1.5 km/h and rotary blade speed was 257 rpm and angle inclination of ‘L’ shape cutting blade with respect to horizontal was 50°. The result draft requirement increased as moisture content of the soil increased and decreased with increased in speed of operation. The effective field capacity of inter-row rotary weeder was found to be 1.43 ha/day. The field efficiency and weeding efficiency was found to be 86.34 % and 92.23 %, respectively.

Niyamapa and Chertkiattipol (2010) carried study on three prototype rotary blades to reduce the tilling torque, impact force and specific tilling tested in a laboratory soil bin with flat tilling surface. Experiments done with the prototype rotary blades and Japanese C-shaped blade were carried out at forward speeds of 0.069 and 0.142 m/s and at rotational speeds of 150, 218, 278 and 348 rpm or 3.30, 4.79, 6.11 and 7.65 m/s by down-cut process in clay soil.The field efficiency and weeding efficiency was found to be 86.34 % and 85.34 %, respectively.

Alizadeb (2011) conducted performance evaluation of four types of mechanical weeders, single row conical weeder (W_1), two rows conical weeder (W_2), rotary weeder (W_3) and power weeder (W_4) and also compared with hand weeding (W_5) in rice. The results among the mechanical weeders, the highest weeding efficiency 84.33 % was obtained with (W_4) power weeder and the lowest value 72.80 % was measured with the rotary weeder (W_3). The average damaged of plants in mechanical weeders was obtained 3.83 % as compared to 0.13 % in hand weeding. The weeding cost was reduced by 15.70 %, 38.51 %, 22.32 % and 48.70 % for W_1, W_2, W_3 and W_4, respectively as compared to W_5.

Olaoye *et al.* (2011) analyzed that the results of the weeder with forward speeds of 0.4 m/s to 0.5 m/s and engine speeds of 1804 to 2261 rpm and concluded that. Weeding tool type had significant effect on the weeding efficiency and on field capacity. The weeding efficiency varied from 54.98 % to 59.05%. The performance of the iron rod tine was better than line yard, cable and plastic tine in terms of weed removal efficiency, field capacity and ease of operation.

Akhijahani *et al.* (2011) investigated the performance of mechanical rotary weeding machine in corn field. Effect of vehicle and rotational speed of machine on the performance of the system and mechanical damage were studied in four levels of speeds. Experiments were done at vehicle speed of 1.27, 2.1, 3.5 and 5.4 km/h and rotational speed of 70, 93, 134 and 184 rpm in corn field havingplants were at the 8-10 leaf stage. The vehicle speed of 5.4 km/h and rotational speed of 134 rpm were found as the optimal speed for cultivation by this machine, considering the maximum performance of system and minimum damage of plant.

Ojomo *et al.* (2012) conducted a study on machine performance parameters by developing and evaluating a motorized weeding machine for 23 effect of moisture content 10 %, 13 % and 16 % and the type of cutting blades flat blade, spike tooth blade and curved blade, on the machine efficiency, quality performance efficiency, percentage of uprooted weeds and percentage of partially uprooted weeds at 16% soil moisture content. The spike tooth blades gave the best mechanical efficiency was 94 %, quality performance efficiency by 84 % of uprooted weeds by 2.8 % and least percentage of partially uprooted weeds by 1.8 %.

Olaoye *et al.* (2012) developed and evaluated a rotary power weeder to reduce the drudgery and ensure a comfortable posture of the operator during weeding and increased production with weeder components parts as frame, rotary hoe disc, tines, power unit and transmission units. The results of field performance evaluation showed that field capacity and weeding efficiency of the rotary power weeder were 0.0712 ha/h and 73% respectively.

Padhee *et al.* (2012) developed comprising of rotary unit and evaluated its performance in the field. It comprised of rotary unit with overall width and rotor diameter of 0.79 mm to 440 mm, respectively. The rotary unit was consisting of 20 'C' type blades arranged spirally on a shaft of diameter 62 mm. The angular interval between the blades was kept 18° to prevent clogging. The speed of rotation of rotor shaft of the developed rotavator was found to be 185 rpm and 230 rpm corresponding to PTO speed of tractor at low and high gears, respectively. Field capacity, field efficiency, tillage performance index and fuel consumption are found to be 0.14 ha/h, 68 %, 0.796 % and 1.56 l/h, respectively during the field evaluation of developed rotavetor.

Ratnaweera *et al.* (2013) designed and fabricated a power weeder. The weeding ability was optimized by weeding three rows simultaneously. The double-action weeding drum was driven by a small 1.3 kW gasoline engine, which can enable removal of weeds, while facilitating the forward motion of the machine. In addition, the conical shaped weeding drums designed to lose the soil without harming the rice. A novel row changing mechanism was helpful for operating the machine by single person without destroying rice. A helical shaped tooth was designed in the weeding drums to enhance the shearing effect for weeding while losing up the soil.

Kankal (2013) designed self-propelled weeder on the basis of agronomic and machine parameters. The main features of prototype self-propelled weeder were, a 4hp petrol start kerosene on run engine, power transmission system, weeding blade sweep and cage wheel. The rated engine speed 3600 rpm was reduced to 23 rpm of the cage wheel by using chain and sprocket mechanism in three steps.Weeding efficiency was found that 75 % for removing shallow-rooted weeds.

Hegazy *et al.* (2014) developed a power weeder for maize crop with modified vertical blades mounted on a circular rotating element on its horizontal side. The motion was transferred to blades units by amended transmission system. The effect of weeder forward speeds, depth of operation, number of blades and soil moisture content on fuel consumption, plant damage, weeding index, effective field capacity, field efficiency, energy required per unit area and total cost were studied. Three levels of soil moisture content 7.73 %, 12.28 % and 16.18 %, the blades arrangements vertical each unit, three weeder forward speeds 1.8, 2.1 and 2.4 km/h and two depths of operation from 0 to 20 and from 20 to 40 mm chosen. The results showed that, the minimum value of fuel consumption was 0.546 l/h and recorded by using two blades with 1.8 km/h weeder forward speed at depth of operation ranged from 0-20 mm and soil moisture content 16.18%. The minimum value of effective field capacity was 0.198 ha/h by using four blades, weeder forward speed 1.8 km/h, soil moisture content 7.73 % and under depth of operation ranged from 20-40 mm. The lower value of total cost was obtained by using two blades with 2.4 km/h weeder forward speed at depth of operation ranged from 0-20 mm and soil moisture content 16.18%.

Gobor and Lammers (2015) developed an intra-row weed control system which consists of a rotary hoe rotating around the horizontal axis above the crop row. The hoeing tool consists of an arm holder and three or more integrated arms rotating around the horizontal axis above the crop row. The weeding tool was attached via a shaft to the motor and the working height of the whole assembly was adjustable. Weeding efficiency was found that 85 % for removing shallow-rooted weeds.

Thorat *et al.* (2017) developed a weeder for ridge planted crops having working components as cutting blades and rotor shaft. Three types of blades L-type, C-type and Flat-type were selected having length, width and thickness of 100 mm, 25 mm and 6mm, respectively, operating with a rotor shaft of 18mm in diameter. C-type blades were most suitable at gang speed of 200 rpm and 15.26±0.96 % (db) soil moisture content with weeding efficiency, plant damage, field capacity of 91.37 %, 2.66 %, and 0.086 ha/h, respectively. Time saving with ridge profile power weeder as compared to manual weeding was 92.97 %.

Advanced Weeding Techniques

Mechanical weeders being used are mostly row crop weeders. The intra row weeding is relatively new concept. Many intra row weeders have been developed, which are generally based on sensors or robots. The review of some of there advanced weeding technique are given below:

Terpstra and Kouwenhoven (1981) found that the use of a hoe ridger for inter row and intra-row weed control result in 57 % of the inter-row weeding by covering with soil and 33 % by uprooting and drying at the soil surface. Also alongside the hoe path, in a band of width 150 to 200 mm, 45 % of the weeds were killed by being covered with soil loosened. They also related that increasing working depth it from 25 mm to 40 mm there is an increase of 10 % in the number of the weeds killed.

Home (2003) suggested that the spacing between the plants to plants is 300 mm the reciprocating intra-row blades avoid entering the root zone up to speeds of 4 km/h, but at 8 km/h 17 percent of the crop root zone was entered. At 250 mm intra-row plant spacing excessive damage was occurred with 70 % of the crop zone being touched by the intra-row blades, and this was also made worse by increasing the working speed. The rotating disc hoe was use in this research work for intra-row weed control.

Weis *et al.* (2008) said that intelligent mechanical weed control would be more suitable for weeding devices with a cutting action instead of tine-based weed removal. It was possible to automatically regulate the inclination of tines of spring-tine harrow prototype systems based on soil conditions, weed density, and crop development. The crop damage increased not only for the broadcast cultivation with the harrow, but also because the intensity with which farmers carried out harrowing. The adjustment of the intensity in cereals was mostly based on the crop growth stage, variations in crop development, weed abundance, and a hard or a loose soil surface that affect harrowing and caused crop damage and non-uniform weed control.

Rueda-Ayala *et al.* (2013) developed a robotic spring-tine harrow for site-specific weed control in narrow row crops such as cereals. The harrow was designed to adjust the tine angle, thereby varying the harrowing intensity while cultivating the crop. The harrow used ultrasonic sensors, which automatically control the harrowing intensity by adjusting the tine angle. The control unit commanded the actuator to move and adjust the tine angle site-specifically according to the plant density variations, in real-time and in one operation. The system performed well at the high driving speeds needed for harrowing operations.

Melander *et al.* (2015) conducted that Robovator cut weeds at 1 to 2 cm soil depth by using a pair of tines, each equipped with a flat knife-like blade. The blades cultivated the interand the intra-row area. When blades approached a crop plant, the blades moved apart to avoid damaging the plant. When the plant passed, the blades closed immediately to continue cultivating the intra-row area. The movement in and out of the crop row was performed by a hydraulic actuator connected to a camera mounted in front of it. There was a camera for each crop row that detected each crop plants based on the different in size between the crop plant and the weeds. The images was processed by a computer to calculatethe points at which the actuator of the blades need to be activated based on the driving speed and the area never cultivated near the crop plants.

Martelloni *et al.* (2017) suggested that transplanted onion and similar non-competitive row crops, intelligent weeding principles need to be supplemented by other means to avoid the subsequent manual hand weeding into the non-treated areas (close proximity to the crop plants). In heat-tolerant non-competitive row crops (i.e., onion, garlic), a good approach would be to equipped the intelligent machines with cross flaming for the entire intra-row.

Merfield and Jabran (2018) developed a Robocrop, a tractor-mounted cultivator, based on a commercially available steerage hoe, equipped with common inter-row cultivation blades, fitted with two hydraulically driven disc modules for each crop row. As the cultivator advanced down the row, a vertical rotating disc controlled by a vision system detected the crop plant location and rotated to align the disc's cut-away section with the saved crop plant. The discs were mounted on a depth control wheel and set to cultivate at a shallow depth 20 mm within the crop rows. Due to variability in crop plant spacing, crop damage was avoided by cutting out a section from the disc's plan profile and rotating it in synchrony with a forward movement in order to ensure that the cut-out section always coincided with the crop plant. The minimum inter-row distance required was 25 cm. The cultivator used cameras, one for each row, to determine the position of the crop plants in real-time for guidance. The plant position was calculated according to the colour, size and expected position. The device could be equipped with a variety of tools (e.g., blades and tines) to guarantee a high level of weed control between and in the crop rows of the crop. A pneumatic cylinder was actuated to open and close the tools around the crop plants. The device was modular, providing working widths ranging from 1.5 to 6 m, and was able to remove weeds from 3 to 4 crop plants along the row in one second. During the operation additional information could be collected such as the density, the cover and a possible alteration in color of the crop.

CONCLUSION

It was clear from the above that many self-propelled and tractor drawn weeding machine have been developed for weeding operation for medium and large farmer, but little work has been carried out for small and marginal farmers. Thus, there is need to developed an efficient weeding machine for small and marginal farmers.

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