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Enhancing Productivity and Nutrient use Efficiency in Winter Maize (*Zea mays* L.) by Pant Fertilizer Band Placement cum Earthing Machine

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Abstract: The experiment was planned to study the effects of Pant fertilizer band placement cum earthing machine on performance of maize and nutrient recovery for two years at G.B. Pant University of Agriculture and Technology. Pantnagar, India. Earthing-cum- urea application was done at knee height stage by Pant Fertilizer Band Placement cum Earthing Machine with different dose of nitrogen. The grain yield, nutrient use efficiency and net return increased due to earthing-cum- urea application by Pant fertilizer band placement cum earthing machine along with a dose of 50 kg N/ha and thereafter top dressing of 50 kg N/ha at tasseling stage.

Keywords: Earthing, Maize, Mechanization, Nitrogen splitting

Maize (*Zea mays* L.) is one of the most versatile emerging crops having wide adaptability and is the only cereal crop that can be grow in different ecologies, seasons and have multiple uses. It is very popular as animal feed, fodder and industrial raw material in the developed countries whereas, in the developing or underdeveloped countries it is mainly used for food and feed. Maize is also an important industrial raw material and provides large opportunity for value addition. Maize is a heavy feeder of nutrients and hence need special care of nutrient management. Nitrogen demand of maize is very high and high rate of urea is applied to the crop requirement. Top dressing of urea in standing maize crop leads to many losses such as ammonia volatilization in high pH soils, nitrate leaching in light texture soils and denitrification in excess soil moisture condition. These losses harm the environment and disturb the whole ecology. Poor nutrient use efficiency of crops and losses of nutrients has increased the importance of proper management of fertilizers. Broadcasting of fertilizers on soil surface causes poor availability of nutrients to crop plants because of fixation of nutrients into soil and formation of many insoluble compounds. The localized nutrient application has been proved beneficial to overcome such problems. Nutrient placement in rhizosphere may be a good option to improve nutrient use efficiency and crop productivity. Localized N and P application in root rhizosphere stimulate root development and establish virtually ideal root architecture and thus increase nutrient uptake and yield of crops (Shen et al 2013). The variable effects of banding of fertilizers on crop growth suggest that the proper placement depth of fertilizers is an effective approach for improvement in crop productivity. Further, as deep bands reduce the losses of nutrients from the soil, there may be possibility to reduce the amount of applied fertilizers. In recent years, banding of fertilizers has become an emerging nutrient management strategy in maize production with the rapid development of agricultural mechanization.

Earthing up is an essential operation in maize crop which prevents the crop from lodging, provides aeration and increases grain yield (Singh et al 2016). Earthing up is a labor intensive operation which is done manually by farmers with a hoe, spade etc. which is very costly and time consuming and energy intensive. Conventionally at knee height stage top dressing is done followed by earthing. Therefore, there is need to, mechanize the top dressing fertilizer dose and earthing up in maize. Regular supply of nitrogen in adequate amount is necessary to increase the maize productivity particularly in winter season when low temperature results in slow growth rate of plants as well as poor absorption of nutrients. Top dressing of urea on soil surface is subjected to various losses such as volatilization, denitrification, leaching and thus nitrogen use efficiency become poor (Jat et al 2016). Placement of urea below the soil surface may prove an effective way to enhance nitrogen use efficiency and thus may be helpful in reducing nitrogen dose (Jat et al 2014).Therefore, keeping this view, Pant fertilizer band placement cum earthing machine was designed and developed in the Department of Farm machinery and Power

Engineering, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar and a field study was conducted for two consecutive winter seasons to assess the impact of mechanized earthing and nitrogen splitting on maize productivity, nutrient use efficiency and profitability.

MATERIAL AND METHODS

The two years field study was conducted during winter season 2016-17 and 2017-18 at G. B. Pant University of Agriculture and Technology, Pantnagar. The experiment consisted of no earthing, manual earthing, inter-cultivation by cultivator and earthing-cum- urea application at knee height stage by Pant fertilizer band placement cum earthing machine. Total nine treatments were executed in randomized block design with three replications (Table 1). Inter-cultivation by cultivator and earthing treatments (manual and by machine) were imposed at knee height stage (94 and 91 days after sowing in both the years, respectively). Except machine treatments, urea was applied @ 50 kg N/ha manually at knee height stage in all the treatments. At tasseling stage, urea was applied manually in all the treatments. Entire amount of P_2O_5 (60 kg/ha) and K_2O (40 kg/ha) and 22.5 kg N /ha were applied as basal. Nitrogen @ 27.5 kg/ha was applied manually at 4-leaf stage in all the treatments. Thus total amount of nitrogen was 110 kg/ha in T_2, 130 kg/ha in T_1, T_4 and T_6 and 150 kg/ha in remaining treatments. The sources of nutrients were NPK fertilizer (12:32:16), urea and muriate of potash. The soil was sandy loam in texture, neutral in reaction (pH 7.3), medium in organic carbon (0.68 %), low in available nitrogen (226 kg/ha), medium in available phosphorus (19.6 kg/ha) and potassium (167 kg/ha).The crop was sown at planting geometry 75 cm × 20 cm on 15 November and 19 November in 2016 and 2017 and harvested on 3rd May 2017 and 1st May 2018, respectively. Hybrid variety NMH 920 was grown as per recommended practices. One pre - sowing irrigation (6 cm) was given to bring the field into optimum moisture condition for germination. The field was prepared by three harrowing and one levelling. Pre-emergence application of atrazine @ 1.0 kg a.i./ha was done next day of sowing. One hand hoeing was also done in all the treatments at 58 and 54 days after sowing in both the years, respectively. The crop was irrigated six times (6 cm each) in both the years. The size of gross and net plots was 15 and 7.2 m^2, respectively. The cobs were harvested manually and were shelled when grain moisture content was about 15 per cent. Stover yield was recorded after sun drying. Nutrient use efficiency for N, P and K was calculated in terms of partial factor productivity (PPF) by dividing yield by respective nutrient dose. Cost of cultivation was calculated by considering current market prices of inputs in local market. Monetary return was obtained by considering market price of grain i.e. Rs. 20/kg. Benefit to cost ratio (B:C) was obtained by dividing net return by cost of cultivation. The data were analyzed by using the online statistical software OP Stat (*Sheoran* et al *1998)*.

Pant fertilizer band placement cum earthing machine (Fig. 1) is a tractor drawn machine which can perform the three main functions, (i) loosening of the soil up to 200 mm depth and cutting the weeds, (ii) placement of chemical fertilizers on the surface of the soil near the plant at a distance

Table 1. Growth response of winter maize to earthing and nitrogen dose

Treatment	Plant height (cm)	Plant population (× 10^3)/ha	No. of cobs (× 10^3)/ha	Days to 50%		Individual cob weight (g)
				Tasseling	Silking	
T_1: Machine Earthing 30 kg N at KH + 50 kg N at tasseling	156.5	61.9	59.4	120.0	123.7	110.6
T_2: Machine Earthing 30 kg N at KH + 30 kg N at tasseling	154.4	62.9	60.7	120.3	123.7	98.4
T_3: Machine Earthing 50 kg N at KH + 50 kg N at tasseling	164.5	61.8	59.9	120.0	124.0	128.3
T_4: Machine Earthing 50 kg N at KH + 30 kg N at tasseling	160.1	61.9	60.5	120.7	123.7	103.9
T_5: Machine Earthing 70 kg N at KH + 30 kg N at tasseling	166.3	61.3	59.2	120.0	124.0	128.5
T_6: Machine Earthing 70 kg N at KH + 10 kg N at tasseling	159.7	61.2	59.7	120.7	124.0	102.2
T_7: Manual earthing	158.7	61.4	59.8	121.0	124.0	110.0
T_8: Inter-cultivation by cultivator	155.6	62.0	59.8	120.0	123.7	108.0
T_9: No earthing	154.5	61.4	60.1	120.3	123.7	102.5
CD (p = 0.05)	4.6	NS	NS	NS	NS	15.5

Machine: Pant fertilizer band placement cum earthing machine, KH: knee height stage

Fig. 1. Pant fertilizer band placement cum earthing machine

of 50-100 mm sideways (iii) earthing-up the plant and covering the fertilizer. The mounting of legs on the frame is such that they can be adjusted in horizontal and vertical plane according to row crop spacing and depth of operation. The working efficiency of machine is 0.75 ha/hr. The machine offers the apparent advantage of timely earthing, weeding, saving of time, fuel and labour costs and therefore, helps reducing the cost of production besides reducing the drudgery of the task.

RESULTS AND DISCUSSION

Growth and development: Mechanized machine earthing with 70 kg N at knee height stage + 30 kg N at tasseling produced significantly taller plants than other treatments except it was on par with machine earthing with 50 kg N at knee height stage + 50 kg N at tasseling (Table 1). Earthing up ensures better aeration and fine tilth in root zone and thus makes favourable conditions to the development of roots. These conditions might result into higher water and nutrient uptake by roots from soil and favoured shoot growth. Further, adequate amount of nitrogen in these treatments helped in better growth. In machine treatments, applied urea was covered by soil and was available to roots. Moreover, band application of urea near to roots facilitated nitrogen acquisition by plants. Chances of gaseous loss of machine applied urea were less because it was properly covered by soil which probably helped in more availability of nitrogen. These conditions might resulted into higher shoot growth and thus more plant height. Similar findings were reported by Painyuli et al (2013).

Planting geometry in all treatment was same which led to at par variation in plant population. Number of cobs per unit area depends on plant population and number of cobs per plant. Non-significant differences in plant population caused statistically same number of cobs/ha among all treatments. Different treatments failed to bring significant differences for days to reach 50% tasseling and 50% silking. Crop took 120 days to reach 50% tasseling while 50% silking stage was attained 3-4 days after 50% tasseling. It indicated that phenology of maize was not altered due to earthing operations and nitrogen dose.

Yield attributes and yield: The yield contributing characters viz., cob length, cob girth, cob weight and 100- grain weight were significantly affected by treatments (Table 2). Yield attributes were significantly more in machine earthing with 50 kg N + 50 kg N at tasseling, and was statistically on par with machine earthing with 70 kg N + 30 kg N at tasseling however, cob length was also statistically on par with manual earthing and cob girth with manual earthing and machine earthing with 50 kg N + 30 kg N at tasseling. Individual cob weight improved significantly due to different tested treatments. Mechanized earthing with 70 kg N at knee height stage + 30 kg N at tasseling gained the maximum individual cob weight (128.5 g). It was statistically at par with mechanized earthing with 50 kg N + 50 kg N at tasseling but had significantly higher cob weight than the remaining treatments. Higher individual cob weight under these treatments was because of higher cob length, cob girth as well as its heavier grains as reflected by 100- grain weight.

Compared to manual earthing, mechanized earthing with 50 kg N + 50 kg N at tasseling achieved 16.6 % heavier cob weight. Better shoot growth under earthing operation specially in machine earthing helped in improving yield attributes. Mechanized earthing with 50 kg N at knee height + 50 kg N at tasseling produced the maximum grain yield (5712 kg/ha) and was on par with 70 kg N at knee height by machine + 30 kg N at tasseling. It recorded significantly higher grain yield than all other treatments. The increase in yield under this treatment was 15.8, 18.5 and 23.5 % more compared to manual earthing, inter-cultivation by cultivator and no earthing, respectively. The higher yield attributes under mechanized earthing resulted into more grain yields. The higher weight of cob under mechanized earthing resulted into more grain yields. Similar results were reported by Bhatnagar and Kumar (2017) and Nath et al (2020). Manual earthing had an edge over no earthing as well as inter-cultivation by cultivator for grain yield but variations were not enough to be significant. Numerically manual earthing improved the grain yield by 6.7% over no earthing treatment. Among mechanized earthing treatments variations in grain yield were due to variation in N dose as mode (mechanized) and timing of N application (knee height and tasseling stage) was

similar in all mechanized earthing treatments. Nitrogen application @ 50 kg/ha at knee height stage and 50 kg/ha at tasseling stage produced statistically at par grain yield with mechanized earthing with 70 kg N at knee height and 30 kg/ha at tasseling stage although former treatment has numerically higher grain yield by 2.7 % over later treatment indicated that optimum dose of N application at tasseling is also essential to get higher productivity. In remaining mechanized earthing treatments, reduction in grain yield was owing to reduction in N dose (Table 1). Stover yield also exhibited the similar trend like grain yield. The highest stover yield (10398 kg/ha) was obtained with application of 50 kg/ha N at knee height and 50 kg /ha N at tasseling stage followed by mechanized earthing. Harvest index remain unaffected dose to different treatments.

Nutrient use efficiency: Nitrogen use efficiency in terms of partial factor productivity of nitrogen (PPF_N) was the lowest (30.8 kg grain/kg N) in no earthing treatment (Table 3). All treatments except T6, T7 and T8 showed significantly superiority over T9. The highest PPF_N was recorded in T2 (40.2 kg grain/kg N). Compared to no earthing treatment, partial factor productivity of phosphorus (PPF_P) and potassium (PPF_K) was significantly higher only in T3 and T5 being maximum in T3 (218 kg grain/kg P and 172.1kg grain/kg K, respectively). PPF is calculated by dividing yield by nutrient dose. Therefore, low nutrient dose and height yield are associated with higher nutrient use efficiency. Nitrogen dose was the lowest in T2 which caused more PPF for nitrogen. A negative relationship between nutrient amount and nutrient use efficiency has been reported by many researchers (Srivastava *et al*., 2018). Phosphorus and potassium doses were similar in all treatments so differences in PPF of P and K were only because of variation in grain yield. Since, treatment consisting of 50 kg N at knee height by machine + 50 kg N at tasseling attained maximum grain yield hence it had the highest PPF_P and PPF_K.

Economics: In comparison to no earthing treatment, none of the treatments showed economic superiority except

Table 2. Effect of earthing and nitrogen dose on yield attributes, grain yield and stover yield and harvest index of winter maize

Treatment	Cob length (cm)	Cob girth (cm)	100-grain weight (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
T_1	14.3	13.2	25.7	4900	8949	35.3
T_2	13.6	13.0	24.9	4424	7935	35.7
T_3	16.1	14.0	27.7	5712	10398	35.4
T_4	14.9	13.6	26.3	4649	8356	35.7
T_5	16.0	14.0	27.4	5560	10125	35.5
T_6	14.4	13.4	26.0	4545	8213	35.6
T_7	15.4	13.6	26.5	4933	8815	35.8
T_8	15.0	13.5	25.8	4821	8671	35.7
T_9	14.3	13.5	24.6	4625	8320	35.7
CD (p=0.05)	0.7	0.4	0.9	581	620	NS

For treatment details see Table 1

Table 3. Nutrient use efficiency and economics of winter maize as affected by earthing and nitrogen dose

Treatment	Partial factor productivity			Net return (Rs./ha)	B:C ratio
	N	P	K		
T_1	37.7	187.0	147.6	58602	1.49
T_2	40.2	168.9	133.3	49345	1.26
T_3	38.1	218.0	172.1	74592	1.88
T_4	35.8	177.4	140.0	53591	1.36
T_5	37.1	212.2	167.5	71551	1.80
T_6	35.0	173.5	136.9	51511	1.31
T_7	32.9	188.3	148.6	52665	1.14
T_8	32.2	184.0	145.2	56212	1.40
T_9	30.8	176.6	139.3	53491	1.37
CD (p=0.05)	4.3	22.2	17.5	11628	0.28

For treatment details see Table 1

mechanized earthing with 50 kg N at knee height by machine + 50 kg N at tasseling and 70 kg N at knee height by machine + 30 kg N at tasseling (Table 3). Machine earthing with 50 kg N + 50 kg N at tasseling fetched significantly higher net returns (Rs. 74592/ha) than rest of the treatments but did not vary statistically with machine earthing with 70 kg N + 30 kg N at tasseling. Net return under machine earthing with 50 kg N + 50 kg N at tasseling was Rs. 21927, 18380 and 21101/ha higher as compared to manual earthing, inter-cultivation by cultivator and no earthing, respectively. Manual earthing had the lowest B:C ratio (1.14) because of more money spent on labourers. mechanized earthing with 50 kg N + 50 kg N at tasseling recorded highest B:C ratio (1.88) and was at par with machine earthing with 70 kg N + 30 kg N at tasseling. These results corroborate the findings of Nath et al (2020) who noted more net return in earthing up operation in maize.

CONCLUSION

From this study it can be inferred that earthing by Pant fertilizer band placement cum earthing machine has potential to increase the nutrient use efficiency and growth of maize in winter season. Use of Pant fertilizer band placement cum earthing machine in winter maize at knee height stage along with application of 50 kg N/ha and thereafter top dressing of 50 kg N/ha at tasseling stage is beneficial to increase grain yield and monetary return.

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