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Impact Assessment of various Tillage and Earthing up Practises on Available Nutrient Status and Productivity of Maize Crop (*Zea mays* L.) in Uttarakhand's Tarai Region

Anil Nath[1*], Naresh Malik[1], Rakesh Kumar[1], Arvind Kumar[1] and Samarth Tewari[2]
[1]Department of Agronomy, College of Agriculture, G.B.P.U.A.&T. Pantnagar, (Uttarakhand), India.
[2]School of Agriculture, Graphic Era Hill University, Bhimtal, (Uttarakhand), India.

(Corresponding author: Anil Nath)*
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ABSTRACT: However, the soil and climatic conditions of India are favourable for cultivation of maize but still India lacks behind many countries in terms of yield and productivity of maize. India accounts for only 2.5 percent of global maize production. India's maize productivity is roughly half that of the global average, one-fifth that of the United States, and less than half that of China. In order to increase the production of maize per unit area, it is very important to focus on such practices which improve the yield rather than clearing more land for cultivation. Maize being a highly sensitive crop requires careful selection of agronomic practices such as tillage and intercultural operations like earthing up for its proper growth and development. Tillage, nutrient and water supply, delay in intercultural operations, weeds etc. are the major factors which affects the yield potential of maize. For the assessment of the effects of various tillage and earthing up practises on available nutrient status of soil and productivity of maize crop in Uttarakhand's *Tarai* region, a field experiment was conducted during the kharif season, 2017 and 2019, at Pantnagar with three levels of tillage practises (T_1- Conventional tillage, T_2 - Minimum tillage, and T_3- Deep tillage) and five levels of earthing up practises (E_1 - Earthing by Pant fertilizer band placement- cum-earthing machine, E_2 - Earthing by Earther, E_3 - Manual Earthing, E_4 - Earthing by cultivator, E_5 - No earthing) with three replications in a split plot design. Deep tillage, which was statistically equivalent to conventional tillage, recorded significantly higher values of available NPK in the soil after crop harvesting in both years when compared to the minimum tillage treatment. In 2017 and 2019, earthing by machine and earthing by earther recorded statistically similar values of available nitrogen in the soil, but they were significantly higher than all other treatments. Deep tillage resulted in a 9% increase in grain yield compared to conventional tillage and a 20% increase compared to minimum tillage. The earthing by pant fertilizer band placement cum earthing machine treatment yielded 9.25 percent more grain than earthing by earther, 20.65 percent more than manual earthing, 22 percent more than earthing by cultivator, and 36 percent more than no earthing treatment. As a result, it is concluded that maize crops can be grown using deep tillage along with earthing up using a Pant fertilizer band placement cum earthing machine to improve soil nutrient status and maize productivity in the Tarai region of Uttarakhand.

Keywords: Maize yield, available NPK, deep tillage, Pant fertilizer band placement and earthing machine.

INTRODUCTION

After rice and wheat, maize is the world's most important cereal crop. Maize is considered to be one of the most versatile crops and this can be attributed to its wider adaptability to varied agro-climatic conditions. Being the Queen of Cereal Crops it is known for its higher productivity potential compared to any other cereal crop.

The global area under maize cultivation is 193.7 million ha, with a productivity of 5.75 t/ha on average (FAOSTAT, 2020). The USA has the world's highest maize production, at around 375 mt, accounting for 36% of total maize production. The United States has the highest productivity in the world, at around 10.5 t/ha, which is nearly double the global productivity. India accounts for only 2.5 percent of global maize production. Maize is grown on approximately 9.20 million hectares in India, yielding approximately 27.23 million tonnes of grain with a productivity of 2.95 tonnes per acre and an annual growth rate of 3-4 percent (MOA&FW, 2018-19). India ranks fourth in terms of area and seventh in terms of maize production. However, while India's soil and climatic conditions are favourable for maize cultivation, it is clear that we lag behind many other countries in terms of yield and productivity. India's maize productivity is roughly half that of the global average, one-fifth that of the United States, and less than half that of China.

In order to increase the production of maize, it is very important to focus on such practices which improve the yield rather than clearing more land for cultivation. Maize being a highly sensitive crop requires careful selection of agronomic practices for its proper growth and development. Tillage, nutrient supply, inadequate water supply, water logging, delay in intercultural operations, weeds, insects pests are the major factors which affects the yield potential of maize. Out of these tillage and intercultural operations like earthing up hold a very important role towards successful cultivation of maize crop.

The continuous heavy conventional tillage resulted development of hard pan, soil compaction, deteriorated soil structure/soil erosion, water logging, reduced root growth/nutrient uptake etc. are resulting into reduced fertility and productivity. All these factors are collectively contributing in reducing the yield potential of maize crops at farmers' field. Thus it becomes essential to find out the alternatives like minimum tillage with rotavator, deep tillage with subsoiling etc. The use of minimum tillage practices for maize production are gaining attention because it reduces hazards like soil erosion, reduces labor requirements, saves time and fuel, improves moisture retention, prevents nutrient loss and ultimately improves the yield (Khurshid *et al*., 2006). When compared to conventional tillage, a rotavator provides faster seedbed preparation and lower draft (Kankal *et al*., 2016). Rotavator tillage gives the dual benefit of cost saving as well as time saving (Paudel *et al*., 2020).The presence of hardpan has a significant impact on maize yield and nutrient uptake (Raza *et al*., 2005). Subsoiling appears to be a viable option because it breaks the hard pan and improves soil structure by increasing soil porosity and percolation (Kumar *et al*., 2018). Subsoiling in maize has been found to increase vertical and horizontal root distribution, as well as grain and dry matter yield, by 6.3 and 3.7 percent, respectively, due to improved soil conditions and root development as a result of subsoiling (Feng *et al*., 2018). Subsoiling also helps to delay leaf senescence after anthesis, allowing the plants to maintain a higher green leaf area and photosynthetic activity, resulting in higher yields (Sun *et al*., 2017).

Apart from tillage practices ,earthing up has significant effects on yield of maize by preventing the lodging of the plants with better root development and better aeration in root zone and protect the plants from water logging which is very harmful in case of maize crop. Earthing up also gives anchorage to the lower whorls of adventitious roots above the soil level which then function as absorbing roots and supports the plant by absorbing nutrients and water (Bhatnagar and Kumar, 2017). Nitrogen top-dressing in maize is done by broadcasting with manual earthing, resulting in very poor fertilizer use efficiency and reduced yield. Manual earthing up is a labor intensive process and because of scarcity of labor, these operations get delay which ultimately reduces the yield potential of the crop. It calls for mechanization of earthing up process so that it can be completed on time. The tractor-drawn 'Pant fertilizer band placement-cum-earthing machine' was designed and developed at the Department of Farm Machinery and Power Engineering, College of Technology, G.B.P.U.A.&T., Pantnagar. This machine has three main functions: (i) loosening the soil up to 200 mm depth and weed cutting, (ii) placing chemical fertilizers on the surface of the soil near the plant at a distance of 50–100 mm sideways, and (iii) earthing-up the plant and covering the fertilizer. The fertilizer is feeded into the machine and calibration is done which ensures the application of right amount of fertilizers in uniform manner. The machine provides the obvious benefit of timely earthing, weeding, saving time, fuel, and labour costs, and thus helps to reduce the cost of cultivation while also reducing the drudgery associated with manual earthing (Bhatnagar and Kumar, 2017).

The above presented facts and figures clearly indicate the problems encountered during cultivation of maize crop related to tillage, inter culture operations like earthing up as well as top dressing of fertilizers and possible solutions to those problems. Keeping the foregoing facts in mind, the current study was designed with the following goals:

- To investigate the possibility of increasing available nutrient status in the soil through various tillage and earthing up practises.
- To determine the best tillage and earthing up operation for increasing maize crop productivity in the Tarai region of Uttarakhand.

MATERIALS AND METHODS

The field experiment was carried out during the kharif season of 2017 and 2019 at Pantnagar which represents the *Tarai* region of Uttarakhand. The climate of the region is broadly humid subtropical with cool winter and hot dry summer. Ten composite soil samples were collected randomly in experimental field at a depth of 0-15 cm, before sowing of crop and they were used for physico-chemical analysis in both the experimental years. The texture of the soil was silty clay loam, with medium organic carbon content, a low available nitrogen content, a medium available phosphorus content, a medium available potassium content, and a neutral reaction. Table 1 shows the results of soil analysis. The treatment included three levels of tillage practises (T_1- Conventional tillage, which consisted of one ploughing with a mould board plough followed by two harrowings, T_2-Minimal tillage, which consisted of two passes of a rotavator at 10 cm depth, and T_3- Deep tillage, which consisted of one pass of a rotavator at 10 cm depth) and five levels of earthing up practises (E_1 - Earthing by Pant fertilizer band placement- cum-earthing machine, E_2 - Earthing by Earther, E_3 - Manual Earthing, E_4 - Earthing by cultivator, and E_5 - No earthing) were tested in a split plot design with three replications. The main plots were subjected to tillage practises, while the subplots were subjected to various earthing up practises. In a block of 15 experimental plots, treatment combinations of both main plots and sub plots were assigned at random. For each replication, this procedure was repeated at random and separately. The layout plan remained the same for both years. Sowing was done in plots measuring 6.0 m 6.0 m in both years. Maize seeds of variety "P 3377" were manually sown in 5 cm deep furrows with 75 cm row spacing. Seeds were planted in the opposite direction of the tillage. To achieve the recommended plant population of maize, plant to plant spacing was kept at 20 cm. In both years, the recommended fertilizer dose

(120:60:40 kg NPK/ha and 20 kg zinc/ha) was applied to the maize crop. The full amount of P, K, and Zn, as well as one-third of the N, were applied as a basal dose at the time of sowing, and the remaining N was top dressed in two equal splits at the knee high and pre-tasseling stages. The N top dressing was completed at the knee high stage, along with earthing up practise. The fertilizer was fed into the Earthing by Pant fertilizer band placement-cum-earthing machine, and the machine applied it automatically. In other treatments, where an earther or cultivator was used and manual earthing was performed, the N fertilizer was top dressed manually in conjunction with the earthing up operation. The N was top dressed manually along the rows of maize plants in treatments where no earthing up was done. In both years of the experiment, a similar fertilizer application schedule was followed. At the time of harvest, yield data were collected. After crop harvesting in both years, soil samples were taken from three locations in each plot at a depth of 0-15 cm and analysed for available nutrients (available nitrogen, available phosphorus, and available potassium in kg/ha). The data from various observations were statistically analysed for split plot design using analysis of variance (ANOVA) (Gomez and Gomez, 1984).

Table 1: The physico-chemical properties of experimental field (0-15 cm depth).

Sr. No.	Parameters	Value		Method applied
		Kharif-2017	*Kharif*-2019	
1.	Texture	Silty clay loam (Sand- 19.6%, Silt- 52.3% and Clay- 28.1%)	Silty clay loam (Sand- 19.5 %, Silt- 53 % and Clay- 28 %)	Hydrometer method (Bouyoucos, 1962)
2.	EC (dS/m at 25°C)	0.40	0.39	Conductivity meter (Singh *et al.*, 2010)
3.	pH (1:2.5 soil water suspension)	7.19	7.18	Beckman Glass Electrode pH meter (Jackson, 1973)
4.	Organic carbon (%)	0.70	0.72	Walkley–Black Modified method (Jackson, 1973)
5.	Available nitrogen (kg/ha)	233.9	232.8	Alkaline $KMnO_4$ (Subbiah and Asija, 1956)
6.	Available phosphorus (kg P/ha)	20.7	21.1	Olsen's extraction method (Olsen *et al.*, 1954)
7.	Available potassium (kg K/ha)	212.4	211.7	Flame emission spectrometry method (Jackson, 1973)

RESULTS AND DISCUSSION

A. Available NPK content in the soil

Various tillage and earthing up practises, after crop harvesting in 2017 and 2019 had a significant impact on the available NPK nutrient in soil (Table 2). The data pertaining to available NPK in soil after harvesting of crop revealed that in 2017, the deep tillage being statistically at par with conventional tillage recorded significantly highest value of available NPK in the soil (233.2 kg/ha, 20.4 kg/ha and 218.4 kg/ ha NPK, respectively in deep tillage treatment and 229.0 kg/ha, 20 kg/ha and 214.4 kg/ha NPK, respectively in conventional tillage treatment) as compared to the minimum tillage treatment (221.1 kg/ha, 19.3 kg/ha and 207.1 kg/ha NPK, respectively). The data recorded in the year 2019 also followed the similar pattern. In 2017 and 2019, the treatment earthing by machine and earthing by earther recorded statistically similar value of available nitrogen in the soil, but it was significantly higher than all other treatments. The data pertaining to available phosphorus in the soil revealed that earthing by machine, earthing by earther and manual earthing was statistically at par with each other in both the years. The data collected on available potassium also followed the similar pattern. In both years, the interaction between different tillage and earthing up practises was found to be non-significant.

Table 2: Available NPK in soil after harvesting of maize as influenced by various tillage and earthing up practises in 2017 and 2019.

Treatments	After harvest					
	Available N(kg ha^{-1})		Available P(kg ha^{-1})		Available K(kg ha^{-1})	
	2017	2019	2017	2019	2017	2019
Tillage						
Conventional tillage	229.0	231.8	20.0	20.3	214.4	215.8
Minimum tillage	221.1	223.9	19.3	19.6	207.1	208.4
Deep tillage	233.2	236.1	20.4	20.6	218.4	219.8
SEm ±	2.13	2.15	0.18	0.19	1.92	2.01
CD (p=0.05)	8.4	8.5	0.7	0.7	7.5	7.9
Earthing up						
Earthing by machine	235.8	238.7	20.6	20.9	220.8	222.3
Earthing by Earther	230.6	233.5	20.1	20.4	216.0	217.4
Manual Earthing	226.1	228.9	19.7	20.0	211.8	213.2
Earthing by cultivator	224.6	227.4	19.6	19.9	210.4	211.7
No earthing	221.6	224.4	19.3	19.6	207.6	208.9
SEm ±	2.94	2.98	0.26	0.26	2.68	2.77
CD (p=0.05)	9.6	9.7	0.8	0.9	9.0	9.0
Interaction (T x E)	NS	NS	NS	NS	NS	NS

B. Cob yield

Different tillage and earthing up practises had a significant impact on maize cob yield in 2017, 2019, and in pooled analysis (Table 3). Different tillage methods had a significant impact on maize cob yield. Deep tillage produced the highest cob yield (6.88 t/ha) in 2017, followed by conventional tillage (6.15 t/ha) and minimum tillage (6.15 t/ha) (5.57 t/ha). The data for cob yield in 2019 as well as in the pooled analysis also showed a similar trend. Different earthing up methods had a significant effect on maize cob yield. In 2017, the treatment earthing by machine had the highest value of cob yield (7.05 t/ha) followed by earthing by earther (6.53 t/ha), manual earthing (6.00 t/ha), earthing by cultivator (5.98 t/ha) and no earthing (5.45 t/ha). A similar trend was observed in 2019 and in data pooled analysis. This could be attributed to the positive effect of earthing up and proper and uniform application of top dressed fertilizers on maize plant growth and development. Bhatnagar and Kumar reported similar findings (2017). In both years and for pooled analysis, the interaction between different tillage and earthing up practises was found to be non-significant.

C. Grain yield

Different tillage methods used in the experiment had a significant impact on maize grain yield (Table 3). In 2017, the deep tillage treatment had the highest grain yield (5.21 t/ha) followed by conventional tillage (4.76 t/ha) and minimum tillage (4.31 t/ha). The data obtained in 2019 and the pooled analysis followed a similar pattern. This is primarily due to the higher yield attributing character values obtained in the deep tillage treatment when compared to conventional and minimum tillage. The findings of Khurshid *et al*. (2006); Wang *et al*. (2015); Cai *et al*. (2014); Ehsanullah *et al*. (2015) and Sun *et al*. (2017) confirmed the same. Different earthing up practises had a significant effect on maize grain yield (Table 3). According to the 2017 data, earthing by machine was statistically equivalent to earthing by earther (5.44 t/ha and 5.04 t/ha, respectively) and resulted in significantly higher grain yield values when compared to other treatments such as manual earthing (4.62 t/ha), earthing by cultivator (4.56 t/ha) and no earthing (4.14 t/ha). In contrast, earthing by machine treatment was found to be significantly superior to all other treatments in 2019 and in pooled analysis. Furthermore, when compared to earthing by earther, manual earthing, earthing by cultivator, and no earthing, earthing by machine yielded 9.3 percent, 20.7 percent, 22.0 percent, and 36.0 percent more grain yield, respectively as per the pooled data. Khan *et al*. (2012); Bhatnagar and Kumar (2017) reported similar findings regarding improved earthing up performance. In both years and for pooled analysis, the interaction between different tillage and earthing up practises was found to be non-significant.

Table 3: Cob yield and grain yield of maize as influenced by various tillage and earthing up practises in 2017 and 2019.

Treatments	Yield					
	Cob yield (t ha^{-1})			Grain yield (t ha^{-1})		
	2017	2019	Pooled	2017	2019	Pooled
Tillage						
Conventional tillage	6.15	6.44	6.30	4.76	4.77	4.77
Minimum tillage	5.57	5.88	5.73	4.31	4.36	4.33
Deep tillage	6.88	7.05	6.97	5.21	5.18	5.20
SEm ±	0.14	0.12	0.04	0.11	0.10	0.09
CD (p=0.05)	0.54	0.46	0.14	0.44	0.40	0.36
Earthing up						
Earthing by machine	7.05	7.64	7.35	5.44	5.65	5.55
Earthing by Earther	6.53	6.84	6.69	5.04	5.11	5.08
Manual Earthing	6.00	6.18	6.09	4.62	4.57	4.60
Earthing by cultivator	5.98	6.15	6.07	4.56	4.53	4.55
No earthing	5.45	5.49	5.47	4.14	3.99	4.07
SEm ±	0.16	0.198	0.15	0.123	0.16	0.12
CD (p=0.05)	0.51	0.64	0.49	0.40	0.53	0.38
Interaction (T x E)	NS	NS	NS	NS	NS	NS

CONCLUSION

Based on the findings of the current investigation, it was determined that the performance of maize crop in the farmer's field can be improved by shifting from conventional methods of planting to more advanced techniques like subsoiler and problems associated with manual earthing up practices can be overcome by mechanized earthing up which will help in increasing the yield and net returns of farmers. Maize crops can be grown using deep tillage and earthing up with a Pant fertilizer band placement cum earthing machine to improve soil nutrient status and maize productivity in the Tarai region of Uttarakhand, and this can be replicated throughout the Indo Gangetic plains of India. The Pant fertilizer band placement cum earthing machine is an excellent choice for interculture operations such as earthing up in maize crop to improve soil fertility and maize crop productivity.

FUTURE SCOPE

This research has its direct utility at the farmer's field to increase the productivity, nutritional quality and also nutrient use efficiency through precise application (Pant fertilizer band placement cum earthing machine) in kharif sown maize under tarai region of Uttarakhand conditions.

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Conflict of Interest. None.

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