Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(5): 2561-2565
Received: 06-06-2020
Accepted: 11-07-2020

Anil Nath
Department of Agronomy, College of Agriculture, G.B.P.U.A.&T. Pantnagar, Uttarakhand, India

Naresh Malik
Department of Agronomy, College of Agriculture, G.B.P.U.A.&T. Pantnagar, Uttarakhand, India

VK Singh
Department of Agronomy, College of Agriculture, G.B.P.U.A.&T. Pantnagar, Uttarakhand, India

Anil Shukla
Department of Agronomy, College of Agriculture, G.B.P.U.A.&T. Pantnagar, Uttarakhand, India

Ramesh Chandra
Department of Soil Science, College of Agriculture, G.B.P.U.A.&T. Pantnagar, Uttarakhand, India

Corresponding Author:
Anil Nath
Department of Agronomy, College of Agriculture, G.B.P.U.A.&T. Pantnagar, Uttarakhand, India

Effect of different tillage and earthing up practices on growth and productivity of maize crop (*Zea mays* L.) in Tarai region of Uttarakhand

Anil Nath, Naresh Malik, VK Singh, Anil Shukla and Ramesh Chandra

Abstract
Maize is the third most important cereal crop in the world as well as in India in terms of area and production. India is producing only 2.5% of the world maize production. India's maize productivity is about half the world's average, 1/5th of the productivity of the US and less than half of China, however, soil and climatic conditions of India are ideal for maize production. The low yield of maize in India may be due to poor agronomic practices of which most important are tillage and earthing up practices. So in order to find out the effect of different tillage and earthing up practices on growth and productivity of maize crop in tarai region of Uttarakhand, a field experiment was conducted during the *kharif* season, 2017 and 2019 at Pantnagar with three levels of tillage practices (T_1- Conventional tillage,T_2 - Minimum tillage and T_3- Deep tillage) and 5 levels of earthing up practices (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) in split plot design with three replications. Significantly higher values of growth attributes of maize were recorded in deep tillage treatment. The deep tillage recorded 9% higher grain yield as compared to conventional tillage treatment and 20% higher as compared to minimum tillage. The significantly higher values of growth attributes of maize were recorded in treatment earthing by pant fertilizer band placement cum earthing machine. The treatment earthing by pant fertilizer band placement cum earthing machine recorded 9.25% higher grain yield as compared to earthing by earther, 20.65% higher than manual earthing, 22% higher than earthing by cultivator and 36% higher than no earthing treatment. Thus the results of this study revealed that maize crop may be grown under deep tillage treatment along with earthing up by pant fertilizer band placement cum earthing machine for better growth and higher productivity in Tarai region of Uttarakhand and also be replicated in whole Indo Gangetic plains of India.

Keywords: Maize productivity, deep tillage, pant fertilizer band placement cum earthing machine

1. Introduction
Maize (*Zea mays* L.) is an important cereal crop with various uses. It is the major source of food, feed, fodder and industrial raw material for the industry for production of starch for textile, pharmaceutical, cosmetic industries, high quality corn oil, protein, alcoholic beverages, food sweeteners etc. and also provides enormous opportunity for crop diversification, value addition and employment generation. Maize is also grown for many other special purposes *viz.* quality protein maize, sweet corn, baby corn, popcorn, waxy corn, high oil and high amylase corn. It is also being recently used in the production of biofuel. Globally, it is known as queen of cereals because of its highest genetic potential among the cereals. Maize is the third most important cereal crop in the world as well as in India in terms of area and production but in terms of productivity, it ranks first followed by rice and wheat.
Maize is cultivated on an area of 196 mha, producing ~1110 mt grains with 5.66 t/ha productivity across the world (FAOSTAT, 2018-19) [6]. The United States of America has the highest production of maize in the world i.e. around 375 mt, which is 36% of the total maize production in the world. USA has the highest productivity in the world i.e. around 10.5 t/ha which is almost double of the global productivity. India is standing at the sixth position in case of production of maize. India is producing only 2.5% of the world maize production. In India, maize is grown in about 9.20 mha area and producing around 27.23 mt grains with 2.95 t/ha productivity and 3-4% annual growth rate (MOA&FW, 2018-19) [14].
However, soil and climatic conditions of India are ideal for maize production, yet its productivity per hectare is very low in comparison to other maize growing countries of the world. India's corn productivity is about half the world's average, 1/5th of the productivity of the US and less than half of China.

The low yield of maize in India may be due to poor agronomic practices of which most important are tillage and intercultural operations. Tillage has been an integrated component of all crops mainly because it provides good soil tilth, improves the water holding capacity, increases aeration and also moderates soil hydraulic conditions (Karami *et al*., 2012) [10]. With the introduction of herbicides in intensive farming systems, the concept of tillage has been changed. Long term conventional tillage or intensive tillage results into increased soil compaction, shallow soil tillage layer, damaged soil structure, soil loss due to erosion, reduced soil aggregates stability which ultimately leads to reduced soil fertility and productivity. Repeated tillage practices with heavy ploughs at same depth leads to development of hard pan. The presence of hard pan restricts the root growth and reduces the water and nutrient uptake. Removal of hard pan may lead to improved crop yield by improving soil structure. The sub soiling is an urgent need to break the hard pan and also improve the soil porosity and percolation (Kumar *et al*., 2018) [13]. Sub soiling reduces the soil strength, improves the soil properties and considerably enhances the crop yield. Therefore, sub soiling is the main tillage system, the use of which is reported in the literature (Bogunovic *et al*., 2018) [3]. In recent years, rotavator is becoming popular among the farmers for land preparation. Rotavator is used for preparing land by breaking the soil with the help of rotating blades without overturning of the soil which is suitable for sowing seeds. It is used mainly to loosen the upper layer of soil to mix the soil with fertilizer and to remove weeds. The rotavator produces a perfect seedbed in fewer passes. It offers an advantage of rapid seedbed preparation and reduced draft compared to conventional tillage (Kankal *et al*.,2016) [9].

Among the intercultural operations, earthing up plays a vital role in making efficient use of irrigation water, minimizing lodging of the crop, destroying weeds and extensive development of root system. Earthing up is an essential operation in maize crop which prevents the plant from lodging with better stand ability. Earthing up provides fine tilth with better aeration in root zone which ensures favourable conditions to root development. Moreover, it also provides anchorage of the lower whorls of adventitious roots above the soil level which then function as absorbing roots (Bhatnagar and Kumar, 2017) [2]. These conditions result into higher water and nutrient uptake by roots from soil. Earthing up also improves the nutrient use efficiency by reducing the losses in the form of volatilization.

Regular supply of nitrogen in adequate amount is necessary to enhance the productivity of maize (Singh *et al.,* 2003) [15]. Top-dressing of nitrogen in maize is done by broadcasting method manually which results in low fertilizer use efficiency. Urea applied by farmers on soil surface is subjected to various losses and causes poor nitrogen use efficiency (Jat *et al*., 2016) [7] as applied N is lost due to volatilization (Jat *et al*., 2014) [8]. 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) [8]. Earthing up covers the top dressed fertilizer and improves both fertilizer use efficiency and yield. But traditional methods of earthing up which is done by hand with a hoe, spade etc. are tedious, laborious, and time consuming which leads to high cost of production. Scarcity of labour delays this earthing up operation that has adverse effect on maize yield. Therefore, there is a need to mechanize the earthing up in maize which will result in saving of time, labour and fertilizer. Tractor drawn cultivator and earther are the most common implements which is mainly used for interculture operations like stirring the soil, destroying the weeds, earthing up etc. For the same purpose, a Pant fertilizer band placement- cum-earthing machine is also designed and developed at the department of farm machinery and power engineering, college of technology, Govind Ballabh Pant University of Agriculture and Technology (GBPUA&T), Pantnagar. Pant fertilizer band placement-cum-earthing machine is tractor-drawn machine which can perform the 3 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 of 50–100 mm sideways, and (iii) earthing-up the plant and covering the fertilizer (Bhatnagar and Kumar, 2017) [2].

Thus there is ample scope for improving growth and increasing productivity of maize crop by adopting different tillage practices and different earthing up operations. The objective of this research was to study the effect of different tillage and earthing up practices on growth and productivity of maize crop in tarai region of Uttarakhand.

2. Materials and Methods

The field experiment was conducted during the *kharif* season, 2017 and 2019 at Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, district Udham Singh Nagar, Uttarakhand, representing the *Tarai* belt of Uttarakhand. Pantnagar is situated in the foot hills of the *Shivalik* range of the Himalayas at 29˚ N latitude, 79.5˚ E longitude and at an altitude of 243.83 m above the mean sea level. The climate of the region is broadly humid subtropical with cool winter and hot dry summer. During summer, the maximum temperature exceeds 40^0 C while in winters the minimum temperature occasionally touches 0^0 C. The mean relative humidity remains almost 80-90 per cent. The soil is silty clay loam in texture, medium in organic carbon, low in available nitrogen, medium in available phosphorus, medium in available potassium and neutral in reaction. The treatment consisted of three levels of tillage practices (T_1- Conventional tillage i.e.1 ploughing with mould board plough followed by 2 harrowings, T_2 - Minimum tillage i.e. 2 pass of rotavator at 10 cm depth and T_3- Deep tillage i.e. Subsoiling at 30 cm depth followed by 1 pass of rotavator at 10 cm depth) and 5 levels of earthing up practices (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 laid out in split plot design with three replications. The tillage practices were considered in the main plots and different earthing up practices were taken in the subplots. The treatment combinations of both main plots and sub plots were allotted randomly in a block having 15 experimental plots. This procedure was repeated randomly and separately for each replication. The layout plan was kept same for both the years. During both the years, sowing was done in plots measuring 6.0 m ×6.0 m. Maize seeds of variety "P 3377" were sown manually in 5 cm deep furrows at a row spacing of 75 cm. Seeds were sown in the opposite direction of the tillage operation. Plant to plant spacing was maintained at 20 cm in order to obtain the recommended plant population of maize. The recommended dose of fertilizers (120:60:40 kg NPK/ha and 20 kg zinc /ha) was applied in the maize crop in both the years. The dose of urea, NPK (12:32:16) and zinc sulphate monohydrate was calculated according to the treatment. Full amount of P, K and Zn and 1/3rd of N was applied as basal dose i.e. at the time of sowing and remaining

N was top dressed in two equal splits at knee high stage and at pre tasseling stage. At knee high stage the N top dressing was done along with earthing up practice. In Earthing by Pant fertilizer band placement-cum-earthing machine the fertilizer was feeded to the machine and the machine applied it automatically. In other treatments where earther or cultivator was used and manual earthing was done the N fertilizer was top dressed manually along with earthing up operation. In treatment where no earthing up was done the N was top dressed manually along the rows of maize plants. Similar schedule of fertilizer application was followed in both the years of experiment. Weed control operations were performed manually in both the years. One hand weeding was done one week after sowing of the crop. The maize crop was irrigated as per the crop requirement. During the entire crop growth period, the crop was irrigated twice in both the years. The observations on growth and development parameters such as field emergence percentage, plant height, leaf area, dry matter accumulation, etc. were recorded at different crop growth stages from the sample rows. Yield data were recorded at the time of harvest.

3. Results and Discussion

The results obtained from the present investigation are presented in Table 1, 2, 3 and 4.

3.1 Field emergence percent

The field emergence percent of maize crop did not get significantly affected by different tillage and earthing up practices (Table-1). The different tillage methods and earthing up practices failed to produce any significant effect on field emergence percent in maize during both the years. This is mainly attributed to the reason that uniform seed rate of same variety was used in all the plots and earthing up treatment was imposed at 25-30 DAS. The interaction between tillage methods and earthing up practices was also found to be non significant in both the years.

3.2 Plant height

The plant height of maize crop was significantly affected by different tillage and earthing up practices at 60 and 90 DAS and at harvest (Table-1). At 30 DAS, the different tillage methods failed to produce any significant effect on plant height. However, at 60 DAS in 2017, the data pertaining to plant height revealed that deep tillage treatment recorded significantly higher plant height (208.9 cm) as compared to conventional tillage (190.8 cm) and minimum tillage (169.6 cm). Similar trend was also recorded for plant height at 60 DAS during the year 2019. At 90 DAS, in 2017, the deep tillage treatment was found to be significantly superior in terms of plant height (229.4 cm) as compared to conventional tillage (208.6 cm) and minimum tillage treatment (184.5 cm). Similar trend was also observed in the year 2019 also. The plant height data at harvesting also followed the similar trend. This could be mainly attributed to the reason that deep tillage promoted better root growth and thus facilitated the plants for better absorption of water and nutrients, which in turn increased the plant height. Similar finding were also reported by Khurshid *et al*. (2006) [12].

The plant height of maize did not get significantly affected by different earthing up practices at 30 DAS. However during the year 2017, at 60 DAS, the treatment earthing by machine recorded significantly highest value of plant height (222.2 cm) as compared to earthing by earther (201.9 cm), manual earthing (185.1 cm), earthing by cultivator (182.9 cm) and no earthing treatment (159.8 cm). Similar trend was also followed at 60 DAS in 2019 and at 90 DAS and at harvest stage during both the years. This could be mainly attributed to the beneficial effect of earthing up and proper placement of top dressed fertilizers on the growth of maize plants. These results are in strong confirmation with the findings of Khan *et al*. (2012) [11] and Bhatnagar and Kumar (2017) [2]. The interaction between tillage methods and earthing up practices was found to be non significant in both the years.

3.3 Leaf area per plant

The leaf area per plant of maize crop was significantly affected by different tillage and earthing up practices at 30, 60 and 90 DAS and at harvest (Table – 2). The different tillage methods have produced significant effect on leaf area per plant of maize crop. At 30 DAS, the significantly highest value of leaf area per plant was recorded in deep tillage treatment (1168 cm^2) as compared to conventional (1049 cm^2) and minimum tillage treatment (950 cm^2) during the year 2017. Similar trend in terms of leaf area per plant was also recorded at all other growth stages in both the years. This could be attributed to the fact that deep tillage promoted better root and shoot growth of the plants and thus resulted in higher number of leaves and higher value of leaf area per plant.

The different earthing up practices also produced a significant effect on leaf area per plant of maize. During the year 2017, at 30 DAS, the significantly highest value of leaf area per plant was obtained in the treatment earthing by machine (1218 cm^2) as compared to other treatments *viz*. earthing by earther (1110 cm^2), manual earthing (1017 cm^2), earthing by cultivator (1038 cm^2) and no earthing (901 cm^2). The data pertaining to leaf area per plant recorded similar trend at all other growth stages in both the years. This could be attributed to the beneficial effects of earthing up and proper placement of top dressed fertilizers.

The interaction between tillage methods and earthing up practices was found to be non significant in both the years.

3.4 Shoot dry matter accumulation

The shoot dry matter accumulation in maize crop was significantly affected by different tillage and earthing up practices at 30, 60 and 90 DAS and at harvest (Table -3).The different tillage methods have produced significant effect on shoot dry matter accumulation in maize crop. At 30 DAS, deep tillage treatment (12.1 g $plant^{-1}$) was found at par with conventional tillage (11.1 g $plant^{-1}$) and significantly superior to minimum tillage treatment (9.6 g $plant^{-1}$) during the year 2017. Deep tillage was significantly superior to other tillage tillage options at all other growth stages in both the years in case of shoot dry matter accumulation in maize crop. This could be attributed to the beneficial effect of deep tillage on growth and development of maize plants. These findings are in strong compliance with the results obtained by Wang *et al*. (2015) [17] and Sun *et al*. (2017) [16].

The different earthing up methods has also significantly affected the shoot dry matter accumulation in maize. At 30 DAS, in 2017, the significantly highest shoot dry matter accumulation was recorded in earthing by machine (12.9 g $plant^{-1}$) as compared to other treatments *viz*. earthing by earther (11.7 g $plant^{-1}$), manual earthing (10.8 g $plant^{-1}$), earthing by cultivator (10.6 g $plant^{-1}$) and no earthing treatment (8.6 g $plant^{-1}$). Similar trend in terms of shoot dry matter accumulation was also recorded at all other growth stages in both the years.This higher dry matter accumulation in shoot is mainly because of the beneficial effect of earthing up on growth and development of maize plants and proper placement of top dressed fertilizers.

The interaction between tillage methods and earthing up practices was found to be non significant in both the years.

3.5 Grain yield

There was a significant effect of different tillage and earthing up practices on grain yield of maize in the year 2017, 2019 and in pooled analysis (Table- 4). Different tillage methods adopted in the experiment significantly affected the grain yield of maize. In 2017, the significantly highest value of grain yield of maize was recorded in deep tillage treatment (52.1 q ha^{-1}) which was followed by conventional tillage (47.6 q ha^{-1}) and minimum tillage (43.1 q ha^{-1}). The data obtained in the year 2019 and in pooled analysis followed the similar trend. This is mainly attributed to the higher values of yield attributing characters obtained in the deep tillage treatment, as compared to conventional and minimum tillage. The results obtained were in confirmation with the findings of Khurshid *et al*. (2006) [12], Cai *et al*. (2014) [4], Ehsanullah *et al*. (2015) [5], Wang *et al*. (2015) [17] and Sun *et al*. (2017) [16].

There was also a significant effect of different earthing up practices on grain yield of maize. The data pertaining to year 2017 revealed that earthing by machine being statistically at par with earthing by earther (54.4 q ha^{-1} and 50.4 q ha^{-1}, respectively) has recorded significantly higher values of grain yield as compared to other treatments *viz*. manual earthing (46.2 q ha^{-1}), earthing by cultivator (45.6 q ha^{-1}) and no earthing (41.4 q ha^{-1}). Whereas, in the year 2019 and in pooled analysis, earthing by machine treatment was found to be significantly superior as compared to all other treatments. Further, the pooled data revealed that earthing by machine recorded 9.25%, 20.65%, 22.% and 36% higher grain yield as compared to earthing by earther, manual earthing, earthing by cultivator and no earthing, respectively. Similar findings related to better performance of earthing up was also reported by Ahmad *et al*. (2000) [1], Khan *et al*. (2012) [11] and Bhatnagar and Kumar (2017) [2]. The interaction between different tillage and earthing up practices was found to be non significant in both the years and for pooled analysis.

Table 1: Field emergence percentage and plant height of maize as affected by different tillage and earthing up practices during 2017 and 2019.

Treatments	Field Emergence percentage		Plant height (cm)							
			30 DAS		60 DAS		90 DAS		At harvest	
	2017	2019	2017	2019	2017	2019	2017	2019	2017	2019
Tillage										
Conventional tillage	75.3	77.6	89.4	94.1	190.8	192.8	208.6	212.1	212.0	217.5
Minimum tillage	74.3	75.6	86.5	87.4	169.6	172.2	184.5	190.4	190.5	196.8
Deep tillage	76.5	78.8	93.0	94.9	208.9	209.9	229.4	231.1	234.2	236.3
SEm ±	1.83	1.89	2.20	1.94	4.50	4.09	4.63	4.68	4.43	4.82
CD (p=0.05)	NS	NS	NS	NS	17.7	16.1	18.2	18.4	17.4	18.9
Earthing up										
Earthing by machine	76.1	78.5	95.6	97.9	222.2	231.3	244.7	256.5	248.7	262.9
Earthing by Earther	76.3	78.6	92.4	94.7	201.9	206.5	221.7	227.8	226.3	233.0
Manual Earthing	76.1	78.4	90.0	93.5	185.1	185.4	203.3	203.7	207.6	208.3
Earthing by cultivator	75.7	78.0	88.0	93.1	182.9	183.2	200.8	202.1	205.0	206.7
No earthing	74.6	75.5	85.5	89.8	159.8	161.5	175.4	177.1	179.5	181.1
SEm ±	1.56	1.61	2.55	1.59	4.91	6.45	5.59	6.99	5.93	7.02
CD (p=0.05)	NS	NS	NS	NS	21.0	18.2	22.8	19.3	22.2	21.0
Interaction (T x E)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Leaf area per plant of maize as affected by different tillage and earthing up practices during 2017 and 2019.

Treatments	Leaf area per plant (cm^2)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2017	2019	2017	2019	2017	2019	2017	2019
Tillage								
Conventional tillage	1049	1046	4466	4574	3851	3916	3564	3595
Minimum tillage	950	955	3905	4081	3265	3324	3025	3078
Deep tillage	1168	1179	5026	5134	4365	4458	4056	4135
SEm ±	21.2	23.4	101.2	96.9	89.5	87.2	78.3	76.1
CD (p=0.05)	83	92	397	380	351	342	308	299
Earthing up								
Earthing by machine	1218	1232	5189	5536	4589	4756	4132	4325
Earthing by Earther	1110	1121	4724	4866	4107	4095	3791	3817
Manual Earthing	1017	1036	4332	4382	3735	3751	3476	3444
Earthing by cultivator	1038	994	4279	4346	3690	3721	3434	3416
No earthing	901	911	3766	3801	3125	3204	2869	2965
SEm ±	23.9	31.2	111.6	152.5	99.7	129.1	96.3	115.7
CD (p=0.05)	78	102	364	497	325	421	314	377
Interaction (T x E)	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Shoot dry matter accumulation of maize as affected by different tillage and earthing up practices during 2017 and 2019

Treatments	Shoot dry matter accumulation (g/plant)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2017	2019	2017	2019	2017	2019	2017	2019
Tillage								
Conventional tillage	11.1	11.3	57.2	57.5	201.3	204.1	222.2	225.9
Minimum tillage	9.6	9.8	50.7	51.4	175.0	179.7	194.9	203.2
Deep tillage	12.1	12.5	64.4	65.3	224.4	232.6	249.3	257.4
SEm ±	0.26	0.26	1.37	1.26	4.96	4.19	5.24	4.71
CD (p=0.05)	1.0	1.0	5.4	5.0	19.5	16.5	20.6	18.5
Earthing up								
Earthing by machine	12.9	13.7	66.1	68.9	233.2	244.3	259.1	266.5
Earthing by Earther	11.7	12.0	60.5	61.5	213.0	216.5	235.1	241.9
Manual Earthing	10.8	10.7	55.5	55.0	195.3	195.3	215.5	216.4
Earthing by cultivator	10.6	10.6	54.8	54.5	192.9	192.0	212.9	213.0
No earthing	8.6	8.8	46.7	47.4	167.2	169.2	187.0	189.1
SEm ±	0.28	0.35	1.44	1.89	5.38	6.61	5.72	7.52
CD (p=0.05)	0.9	1.1	4.7	6.2	17.6	21.6	18.7	24.5
Interaction (T x E)	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Grain yield of maize as affected by different tillage and earthing up practices during 2017 and 2019

Treatments	Grain yield (q/ha)		
	2017	2019	Pooled
Conventional tillage	47.6	47.7	47.7
Minimum tillage	43.1	43.6	43.3
Deep tillage	52.1	51.8	52.0
SEm ±	1.12	1.01	0.90
CD (p=0.05)	4.4	4.0	3.6
Earthing by machine	54.4	56.5	55.5
Earthing by Earther	50.4	51.1	50.8
Manual Earthing	46.2	45.7	46.0
Earthing by cultivator	45.6	45.3	45.5
No earthing	41.4	39.9	40.7
SEm ±	1.23	1.62	1.16
CD (p=0.05)	4.0	5.3	3.8
Interaction (T x E)	NS	NS	NS

4. Conclusion

The result of this study revealed that maize crop may be grown under deep tillage treatment along with earthing up by pant fertilizer band placement cum earthing machine for better growth and higher productivity in Tarai region of Uttarakhand and also be replicated in whole Indo- Gangetic plains of India.

5. Reference

1. Ahmad R, Wahla IH, Cheema ZA, Ullah E. Effect of different inter tillage practices on growth and yield of spring maize. Pakistan Journal of Biological Sciences, 2000; 3(9):1403-1405.
2. Bhatnagar A, Kumar A. Fertilizer band placement-cum-earthing machine effects on growth, productivity and profitability of maize (*Zea mays*) under varying nitrogen levels. Indian Journal of Agronomy. 2017; 62(1):65-69.
3. Bogunovic I, Pereira P, Kisic I, Sajko K, Sraka M. Tillage management impacts on soil compaction, erosion and crop yield in Stagnosols (Croatia). *Catena*. 2018; 160:376-384.
4. Cai H, Ma W, Zhang X, Ping J, Yan X, Liu J *et al*. Effect of subsoil tillage depth on nutrient accumulation, root distribution, and grain yield in spring maize. The Crop Journal. 2014; 2(5):297-307.
5. Ehsanullah, Ashraf U, Anjum SA, Ehsan F, Khan I, Ghaffar A. Tillage practices and sowing methods affrect yield and related attributes of maize. Asian Journal of Agriculture and Biology, 2015; 3(1):8-14.
6. Faostat. 2018-19. Food and Agriculture Organisation of United Nations. http://www.fao.org/faostat.com.
7. Jat HS, Jat RK, Singh Y, Parihar CM, Jat SL, Tetarwal JP *et al*. Nitrogen management under conservation agriculture in cereal-based systems.*Indian Journal of Fertilizers*. 2016; 12(4):76-91.
8. Jat SL, Parihar CM, Singh AK, Kumar A, Sharma S. Nitrogen management under conservation agriculture for enhancing resource-use efficiency in intensified maize systems. (In) *Abstracts of 12th Asian Maize Conference andExpert Consultation on Maize for Food, Feed, Nutrition andEnvironmental Security*" at Bangkok, Thailand, 2014, 98.
9. Kankal US, Karale DS, Thakare SH, Khamballkar VP. Performance evaluation of tractor operated rotavator in dry land and wet land field condition. International Journal of Agricultural Science and Research. 2016; 6(1):137-146.
10. Karami A, Homaee M, Afzalina SHS. Organic resource management impact of soil aggregate stability and soil physicochemical properties.*Journal of Agriculture and Environment*. 2012; 148:22-14.
11. Khan MB, Rafiq R, Hussain M, Farooq M, Jabran K. Ridge sowing improves root system, phosphorus uptake, growth and yield of maize (*Zea mays* L.) hybrids. Journal of Animal and Plant Sciences, 2012; 22(2):309-317.
12. Khurshid K, Iqbal M, Arif MS, Nawaz A. Effect of tillage and mulch on soil physical properties and growth of maize. International Journal of Agriculture and Biology, 2006; 8(5):593-596.
13. Kumar A, Pal MS, Bhatnagar A, Qureshi A. Effect of tillage and nutrient management on growth, yield and harvest index of corn (*Zea mays* L.) in Indo-Gangetic plains of India. International Journal of Current Microbiology and Applied Sciences. 2018; 7:4185-4191.
14. MOA&FW. 2018-19. Ministry of Agriculture & Farmers' Welfare. http://agriculture.gov.in.
15. Singh RN, Sutaliya R, Ghatak R, Sarangi SK. Effect of higher application of nitrogen and potassium over recommended level on growth yield and yield attributes of late sown winter maize (*Zea mays* L.). *Crop Research*. 2003; 26(1):71-74.
16. Sun X, Ding Z, Wang X, Hou H, Zhou B, Yue Y, Ma W, *et al*. Subsoiling practices change root distribution and increase post anthesis dry matter accumulation and yield in summer maize. *PLoS ONE*, 2017; 12(4):E0174952.
17. Wang X, Zhou B, Sun X, Yue Y, Ma W, Zhao M. Soil Tillage Management Affects Maize Grain Yield by Regulating Spatial Distribution Coordination of Roots, Soil Moisture and Nitrogen Status. *PLoS ONE*, 2015; 10(6):1-19.