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AGRONOMY

Nutrients Uptake and Available Nutrients Status in Soil as Influenced by Sowing Methods and Herbicides in *Kharif* Maize (*Zea mays* L.)

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ABSTRACT

An investigation was carried out at Varanasi during *kharif* season of 2015 and 2016 to assess the influence of three sowing methods (ridge and furrow, conventional flat bed and raised bed planting) and seven weed-control methods (tembotrione 100 g ai. ha^{-1} (PoE), tembotrione 125 g ai g ai. ha^{-1} (PoE), atrazine 1 kg ai. ha^{-1} followed by one hand weeding at 30 DAS, atrazine 1 kg ai. ha^{-1} (PE) followed by 2, 4-D at 30 DAS (0.5 kg ai. ha^{-1}, PoE), pendimethalin 1 kg ai. ha^{-1} (PE) followed by one hand weeding at 30 DAS, weedy check and weed free) on nutrient uptake and available nutrients in maize. Raised bed planting has sown results of the lowest weed dry matter accumulation, depletion of NPK by weeds and the highest grain and straw yield, NPK uptake by crop and the available NPKS and Zn in soil than conventional flat bed sowing and it was at par with ridge and furrow sowing. Among the herbicidal treatments, sequential application of atrazine followed by 2, 4-D at 30 was recorded with the lowest dry matter of weeds, NPK depletion by weeds and the highest yield and nutrients uptake and available nutrients in soil when compared to tembotrione 125 g ai g ai ha^{-1} (PoE), tembotrione 100 g ai. ha^{-1} (PoE) and weedy check, respectively and it were statistically at par with weed free, atrazine 1 kg ai. ha^{-1} followed by one hand weeding at 30 DAS and pendimethalin 1 kg ai. ha^{-1} (PE) followed by one hand weeding at 30 DAS, respectively.

Highlights

- Raised bed planting recorded the lowest weed dry weight, nutrients depletion by weeds and the highest grain and straw yield and nutrients uptake by crop and the available nutrients in soil.
- Sequential application of atrazine 1 kg ai. ha^{-1} (PE) followed by 2, 4-D at 30 DAS (0.5 kg ai. ha^{-1}, PoE), recorded the lowest weed dry weight, nutrients depletion by weeds and the highest grain and straw yield and nutrients uptake by crop and the available nutrients in soil.

Keywords: Available nutrients, Maize, Nutrients uptake, Weed, Yield

Maize (*Zea mays* L.) is the third most important cereal crop in India after rice and wheat. The cereals occupy about 54per cent of the total cropped area of which maize occupies about 3.61 per cent of the total cropped area of India. It accounts for 9 per cent of the total food grain production in the country. Karnataka, Rajasthan, Andhra Pradesh, Maharashtra, and Uttar Pradesh are the major maize producing states, which together contribute 60 per cent of area and 70 per cent production in country (Trivedi *et al*. 2017). Successful maize production depends on the correct application of production inputs that will sustain the environment as well as the agricultural production. These inputs are, inter alia, adapted cultivars, plant population, soil tillage, fertilisation, weed, insect and disease control, harvesting, marketing and financial resources (Kalhapure *et al*. 2013). Amongst these production factors, weed management plays a major role in increasing the productivity of maize (Barla *et al*. 2016). Unchecked weed growth in maize crop may result in grain yield losses to the extent of 28-100%

(Das *et al*. 2012) and the nutrient loss varies from 30 to 40% of the applied nutrients (Chopra and Angiras 2008). Management of weeds through integration of crop establishment methods with herbicides can increase the uptake of nutrients and productivity of the crop by decreasing the biomass and nutrient removal by the weeds. Chemical weed management by using pre- or post-emergence herbicides can lead to efficient and cost effective control of weeds during the critical period of crop weed competition, which may not be possible in manual or mechanical weeding due to its high cost of cultivation (Triveni *et al*. 2017). Keeping the above aspects in view, the present investigation was carried out to find out the effect of sowing methods and herbicides on nutrients concentration and their uptake and available nutrients status in soil in maize.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* season of 2015 and 2016 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25° 18′- N latitude, 83° 03′- E longitude and altitude of 129 m above mean sea level). The soil of the experimental field was sandy clay loam in texture, with slightly alkaline in reaction (pH 7.8). It was moderately fertile, being low in available organic carbon (0.359 %), available nitrogen (201 kg ha^{-1}), available phosphorus (15.5 kg ha^{-1}) and potassium (233 kg ha^{-1}). Average values for bulk density 1.42 g cm^{-1}, particle density 2.62 g cm^{-1}, filed capacity 19.57 per cent, permanent wilting point 4.31 per cent and EC were 0.181 dS m^{-1}. Twenty one treatment combinations of three crop establishment methods *viz*. ridge and furrow, conventional flat bed and raised bed planting in the main plot and seven weed-control methods *viz*. tembotrione 100 g ai. ha^{-1} (PoE), tembotrione 125 g ai g ai ha^{-1} (PoE), atrazine 1 kg ai. ha^{-1} followed by one hand weeding at 30 DAS, atrazine 1 kg ai. ha^{-1} (PE) followed by 2, 4-D at 30 DAS (0.5 kg ai. ha^{-1}, PoE), pendimethalin 1 kg ai. ha^{-1} (PE) followed by one hand weeding at 30 DAS, weedy check and weed free were allocated to the sub plots. They were evaluated under split-plot design with three replications. Maize variety ′PAU 352′ was sown under different crop establishment methods at 60x20 cm row spacing by a machine. All the herbicides were applied as the treatment (pre and post emergence) with the help of foot sprayer fitted with flat fan nozzle. The spray volume was 500 litres water ha^{-1}. Half amount of nitrogen and full dose of phosphorus and potash were applied as basal at the time of sowing, ¼ part of nitrogen was top dressed at knee-high stage and remaining ¼ part of nitrogen was top dressed at tassel initiation stage. The nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and murate of potash, respectively. Standard agronomic practices were followed to raise the crop. Weeds were removed from an area of 0.25m^2 from the randomly selected 3 spots by throughing a quadrate of 0.5x0.5m ^{at} 80 days after sowing. The collected weeds were first sun-dried and then kept in an electric oven at 60^o C till the weight became constant, and dry weight was expressed as g/m^2. As wide variation existed in data, number and dry weight of weeds were transformed through squire-root $\sqrt{(x+0.5)}$ methods before the analysis of variance. Maize was harvested manually, but was threshed by power operated thresher and the yield of crop was recorded. The nutrients content and their depletion by weeds were worked out at 80 days after sowing. Available nutrients in soil and nutrient contents in crop were determined as per the standard procedures at harvest and the uptake values were worked out. Nutrient uptake (kg ha^{-1}) were calculated by multiplying their nutrient concentration with weed biomass and crop yield. The experimental data were analysed statistically and were interpreted.

RESULTS AND DISCUSSION

Dry weight of weed

Sowing methods significantly influenced the dry weight of weeds (Table 1). The maximum dry weight of weed was recorded under the conventional flat bed sowing, which facilitates an adequate growing environment to the weeds. Raised bed planting recorded the lowest dry weight of weed when compared to conventional flat bed and it was statistically at par with ridge and furrow sowing. Raised bed planting and ridge and furrow sowing, perhaps owed to the delay in the emergence of weeds due to the presence of less moisture content in the top layer under these two sowing methods when compared with the conventional flat bed

Table 1: Effect of crop establishment methods and weed management practices on nutrient content in weeds

Treatment	Nutrient content (%) at 80 DAS					
	N		P		K	
	2015	2016	2015	2016	2015	2016
Crop establishment methods						
Ridge and furrow	1.878	1.839	0.321	0.317	1.983	1.957
Conventional flat bed	1.869	1.830	0.319	0.315	1.979	1.953
Raised-bed planting	1.870	1.831	0.318	0.314	1.977	1.953
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Weed management practices						
Tembotrione 100 g a.i. ha^{-1} at 30 DAS	1.869	1.830	0.314	0.312	1.975	1.950
Tembotrione 125 g a.i. ha^{-1} at 30 DAS	1.870	1.831	0.316	0.312	1.978	1.952
Atrazine 1 kg a.i. ha^{-1}(PE) followed by one hand weeding at 30 DAS	1.879	1.839	0.324	0.320	1.989	1.963
Atrazine (1 kg a.i. ha^{-1},PE) followed by 2,4-D at 30 DAS (0.5 kg a.i ha^{-1})	1.881	1.841	0.326	0.322	1.993	1.967
Pendimethalin (1kg a.i. ha^{-1}, PE) followed by one hand weeding at 30 DAS	1.873	1.834	0.318	0.314	1.981	1.955
Weedy check	1.839	1.800	0.301	0.297	1.931	1.906
Weed free (hand weeding at 20 and 40DAS)	1.893	1.853	0.332	0.328	2.011	1.985
CD (p=0.05)	0.013	0.010	0.006	0.006	0.013	0.012

Table 2: Effect of crop establishment methods and weed management practices on nutrients uptake by weeds

	Weed dry weight at 80 DAS kg ha^{-1}		Nutrient uptake (kg ha^{-1})					
			N		P		K	
	2015	2016	2015	2016	2015	2016	2015	2016
Crop establishment methods								
Ridge and furrow	332.8	314.6	6.25	5.79	1.07	1.00	6.60	6.16
Conventional flat bed	387.0	365.8	7.23	6.69	1.23	1.15	7.66	7.14
Raised-bed planting	282.3	266.9	5.28	4.89	0.90	0.84	5.58	5.21
CD (p=0.05)	52.1	54.3	1.93	1.79	0.32	0.29	2.06	1.91
Weed management practices								
Tembotrione 100 g a.i. ha^{-1} at 30 DAS	388.7	367.4	7.26	6.72	1.22	1.15	7.68	7.16
Tembotrione 125 g a.i. ha^{-1} at 30 DAS	363.0	343.1	6.79	6.28	1.15	1.07	7.18	6.70
Atrazine 1 kg a.i. ha^{-1} (PE) followed by one hand weeding at 30 DAS	252.4	238.6	4.74	4.39	0.82	0.76	5.02	4.68
Atrazine (1 kg a.i. ha^{-1}, PE) followed by 2,4-D at 30 DAS (0.5 kg a.i ha^{-1})	175.1	165.5	3.29	3.05	0.57	0.53	3.49	3.26
Pendimethalin (1kg a.i. ha^{-1}, PE) followed by one hand weeding at 30 DAS	284.3	268.8	5.33	4.93	0.90	0.84	5.63	5.25
Weedy check	874.1	826.3	16.08	14.87	2.63	2.45	16.88	15.75
Weed free (hand weeding at 20 and 40DAS)	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00
CD (p=0.05)	37.8	41.4	1.47	1.36	0.27	0.25	1.55	1.45

sowing. Similar results were also reported by Chopra and Angiras (2008).

Weed management practices were found to reduce the dry weight of weeds than weedy check in both the years (Table 1). Removing the weeds whenever they appear under the weed free treatment resulted in complete elimination of weed competition as it resulted in zero weed dry weight. The weed free treatments performed better than all the herbicidal treatments in reducing the biomass of weeds. Among the herbicidal treatments, sequential application of atrazine 1 kg ai. ha^{-1} (PE) followed by 2, 4-D at 30 DAS (0.5 kg ai. ha^{-1}, PoE), recorded the lowest dry weight of weeds when compared to tembotrione 100 g ai. ha^{-1} (PoE), tembotrione 125 g ai g ai ha^{-1} (PoE) and it was statistically at par

with atrazine 1 kg ai. ha^{-1} followed by one hand weeding at 30 DAS and pendimethalin 1 kg ai. ha^{-1} (PE) followed by one hand weeding at 30 DAS, respectively. These findings are in conformity with the findings of (Lakshmi and Luther 2017).

Nutrients content in weed and crop

Nutrient content in weeds and crop was unaffected by the sowing methods and herbicides during both the years. But the values of NPK content in weeds were the highest in raised bed planting and sequential application of atrazine 1 kg ai. ha^{-1} (PE) followed by 2, 4-D at 30 DAS (0.5 kg ai. ha^{-1}, PoE) in sowing methods and herbicides, respectively during both the years (Table 2).

Nutrient depletion by weeds

The weeds usually grow faster than the associated crop plants and thus absorb the available nutrients in more amount and lead to the deficiency of nutrients in the crop plants (Table 3). Competition begins when the root system of the crop and weeds overlap in the exploring soil profile and shows the enhanced competition for nutrients.

The minimum depletion of nutrients (NPK) by weeds was recorded under raised bed planting over conventional flat bed sowing and it was at par with ridge and furrow sowing. This might be due to less dry matter accumulation by weeds under raised bed planting. Vigorous growth and higher biomass of weeds resulted in more nutrient depletion under conventional flat bed sowing.

Weed management practices significantly influenced the N, P and K depletion by weeds. It was the highest under tembotrione 100 gai. ha^{-1} (PoE) and tembotrione 125 g ai. ha^{-1} (PoE). The increase in the depletion of N, P and K by weeds under this treatment was due to the poor control of weeds that resulted in the highest dry weight of weed. Sequential application of atrazine 1 kg ai. ha^{-1} (PE) followed by 2, 4-D at 30 DAS (0.5 kg ai. ha^{-1}, PoE), recorded the lowest dry weight and it was statistically at par with atrazine 1 kg ai. ha^{-1} followed by one hand weeding at 30 DAS and pendimethalin 1 kg ai. ha^{-1} (PE) followed by one hand weeding at 30 DAS, respectively during both the years. This might be due to effective control of weeds that resulted in less nutrient uptake by weeds in these treatments. Weedy check registered the highest potassium uptake by weeds at 30 and 60 DAS,

Table 3: Effect of crop establishment methods and weed management practices on nutrients content in maize stover (%)

Treatment	N content		P content		K content	
	2015	2016	2015	2016	2015	2016
Crop establishment methods						
Ridge and furrow	1.48	1.46	0.39	0.35	1.32	1.39
Conventional flat bed	1.51	1.48	0.40	0.36	1.33	1.41
Raised-bed planting	1.49	1.47	0.39	0.35	1.30	1.39
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Weed management practices						
Tembotrione 100 g a.i. ha^{-1} at 30 DAS	1.49	1.48	0.39	0.36	1.32	1.40
Tembotrione 125 g a.i. ha^{-1} at 30 DAS	1.49	1.47	0.38	0.35	1.31	1.40
Atrazine 1 kg a.i. ha^{-1}(PE) followed by one hand weeding at 30 DAS	1.48	1.46	0.38	0.34	1.30	1.39
Atrazine (1 kg a.i. ha^{-1},PE) followed by 2,4-D at 30 DAS (0.5 kg a.i ha^{-1})	1.48	1.46	0.39	0.35	1.31	1.40
Pendimethalin (1kg a.i. ha^{-1}, PE) followed by one hand weeding at 30 DAS	1.49	1.44	0.38	0.34	1.32	1.40
Weedy check	1.52	1.50	0.41	0.38	1.34	1.42
Weed free (hand weeding at 20 and 40DAS)	1.48	1.45	0.40	0.36	1.31	1.40
CD (p=0.05)	NS	NS	NS	NS	NS	NS

Table 4: Effect of crop establishment methods and weed management practices on nutrients content in maize grain (%)

Treatment	N content		P content		K content	
	2015	2016	2015	2016	2015	2016
Crop establishment methods						
Ridge and furrow	1.78	1.76	0.51	0.50	1.76	1.74
Conventional flat bed	1.81	1.79	0.53	0.52	1.82	1.78
Raised-bed planting	1.79	1.78	0.52	0.50	1.73	1.72
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Weed management practices						
Tembotrione 100 g a.i. ha^{-1} at 30 DAS	1.79	1.80	0.52	0.51	1.80	1.76
Tembotrione 125 g a.i. ha^{-1} at 30 DAS	1.79	1.79	0.52	0.51	1.77	1.75
Atrazine 1 kg a.i. ha^{-1} (PE) followed by one hand weeding at 30 DAS	1.78	1.77	0.51	0.49	1.75	1.74
Atrazine (1 kg a.i. ha^{-1},PE) followed by 2,4-D at 30 DAS (0.5 kg a.i ha^{-1})	1.77	1.75	0.51	0.50	1.73	1.74
Pendimethalin (1kg a.i. ha^{-1}, PE) followed by one hand weeding at 30 DAS	1.80	1.73	0.52	0.50	1.77	1.75
Weedy check	1.81	1.82	0.57	0.55	1.83	1.79
Weed free (hand weeding at 20 and 40DAS)	1.78	1.75	0.51	0.50	1.72	1.74
CD (p=0.05)	NS	NS	NS	NS	NS	NS

which can be attributed to the lowest weed control in these treatments. Similar results were reported by Lakshmi and Luther (2017).

Grain and straw yield

Grain and straw yield is an ultimate result of growth and yield components (Table 3 and 4). Sowing methods and herbicides showed significant influence on crop yield. Raised bed planting recorded the highest grain and straw yield than the conventional flat bed methods and it was at par with ridge and furrow sowing. This result indicated that increase in yield under raised bed planting and ridge and furrow sowing was due to the better growing environment than conventional flat bed method of sowing. Results are the corroborated research findings of Malviya *et al*. (2012).

Significantly, the highest grain and straw yield were recorded under the sequential application of atrazine 1 kg ai. ha^{-1} (PE) followed by 2, 4-D at 30 DAS (0.5 kg ai. ha^{-1}, PoE), than tembotrione 100 g ai. ha^{-1} (PoE) and tembotrione 125 g ai. g ai ha^{-1} (PoE) and it was statistically at par with atrazine 1 kg ai. ha^{-1} followed by one hand weeding at 30 DAS and pendimethalin 1 kg ai. ha^{-1} (PE) followed by one hand weeding at 30 DAS.

The reason for higher values on growth parameter can be discussed in the light of fact that crop under this treatment had comparatively less weed competition. The reduction in weed competition in maize by the use of herbicides or hand weeding not only favoured the crop growth with abundant availability of moisture, nutrients, light and space, but also reduced the overall weed interference, facilitating vigorous growth and the development of crop plants and finally produced more grain and straw yield. The lowest grain and straw yield was recorded in weedy check because of more weed growth and poor performance of yield attributing characters. Relative weed free situation under herbicidal treatments reduced the crop weed competition and thus lead to higher vegetative growth and yield attributes that affected the grain and straw yield. These results are corroborated with the findings of Srividya *et al*. (2011), Sanodiya *et al*. (2013) and Singh *et al*. (2014).

Nutrients uptake by crop

Sowing methods and herbicides application significantly influenced the N, P and K uptake by maize (Table 5). Raised bed planting recorded the maximum uptake of N, P and K, whereas it was the lowest in conventional flat bed sowing. It can be

Table 5: Effect of crop establishment methods and weed management practices on total nutrients uptake by maize crop (kg ha^{-1})

Treatment	N		P		K	
	2015	2016	2015	2016	2015	2016
Crop establishment methods						
Ridge and furrow	182.0	193.5	50.1	50.8	171.7	187.6
Conventional flat bed	176.8	188.0	49.5	50.3	166.7	182.9
Raised-bed planting	188.5	198.6	52.2	51.7	173.9	190.1
CD (p=0.05)	6.51	5.11	2.11	0.91	5.21	5.89
Weed management practices						
Tembotrione 100 g a.i. ha^{-1} at 30 DAS	177.5	189.8	49.1	50.0	168.4	182.6
Tembotrione 125 g a.i. ha^{-1} at 30 DAS	182.0	193.7	49.8	50.7	170.6	186.8
Atrazine 1 kg a.i. ha^{-1} (PE) followed by one hand weeding at 30 DAS	187.4	198.5	51.0	50.8	174.8	192.1
Atrazine (1 kg a.i. ha^{-1}, PE) followed by 2,4-D at 30 DAS (0.5 kg a.i ha^{-1})	189.1	201.3	52.3	53.0	176.6	196.3
Pendimethalin (1kg a.i. ha^{-1}, PE) followed by one hand weeding at 30 DAS	186.5	192.6	50.9	50.9	174.8	191.3
Weedy check	159.0	171.7	46.5	47.7	150.5	165.7
Weed free (hand weeding at 20 and 40DAS)	192.0	201.9	53.6	54.0	178.1	197.7
CD (p=0.05)	4.62	3.42	2.02	0.86	4.59	4.62

attributed to the better growing conditions under this (raised bed planting) treatment during growth and development of crop, which can help in the better utilization of nutrient, thereby resulting in highest yield and nutrient uptake.

Among the weed management practices, mixed application of sequential application of atrazine 1 kg ai. ha^{-1} (PE) followed by 2, 4-D at 30 DAS (0.5 kg ai. ha^{-1}, PoE), recorded the highest N, P and K by crop over tembotrione 100 g ai. ha^{-1} (PoE) and tembotrione 125 g ai. ha^{-1} (PoE) and it was statistically at par with atrazine 1 kg ai. ha^{-1} followed by one hand weeding at 30 DAS and pendimethalin 1 kg ai. ha^{-1} (PE) followed by one hand weeding at 30 DAS. The increase in the uptake of nutrients by crop was due to the fact that lower dry weight of weeds under this treatment helps in the better utilization of nutrients by crop. The higher uptake of these nutrients was due to higher yield, higher dry matter production and higher nutrient content in different parts of the plant. Significantly, the highest nutrients uptake was recorded under weed free situation due to higher grain and straw yield of maize. Higher NPK uptake by crops in weed free plots was reported by Lakshmi and Luther (2017). This was due to the reduced depletion of nutrients by weeds and concomitant increase in the absorption and translocation of higher concentration of these nutrients to different maize plant parts for enhanced photosynthetic efficiency, which corroborated with the findings of Malvia *et al*. (2012), Sanodiya *et al*. (2013) and Singh *et al*. (2014).

Available nutrients

OC, EC and soil pH

The effect of sowing methods and herbicides on OC, EC and pH was non-significant. Among the crop establishment methods, slightly highest organic carbon and the lowest pH and electrical conductivity were found under raised bed planting followed by ridge and furrow sowing and conventional flat bed sowing, respectively (Table 6).

Amongst the herbicidal treatments, sequential application of atrazine 1 kg ai. ha^{-1} (PE) followed by 2, 4-D at 30 DAS (0.5 kg ai. ha^{-1}, PoE), recorded the highest organic carbon and lower pH and electrical conductivity than the other weed management practices. Similarly, weed free had maximum organic carbon and minimum pH and electrical conductivity than rest of the treatments.

Table 6: Effect of crop establishment method and weed management practices on yield, OC pH and EC in *kharif* maize

Treatment	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Organic carbon (%)		pH		EC (dS m^{-1})	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Crop establishment methods										
Ridge and furrow	5309	5612	5928	6489	0.352	0.356	7.86	7.79	0.188	0.177
Conventional flat bed	5045	5367	5644	6211	0.350	0.352	7.86	7.79	0.189	0.179
Raised-bed planting	5494	5711	6056	6600	0.354	0.360	7.85	7.78	0.186	0.175
CD (p=0.05)	261	242	282	276	NS	NS	NS	NS	NS	NS
Weed management practices										
Tembotrione 100 g a.i. ha^{-1} at 30 DAS	5128	5388	5752	6256	0.349	0.354	7.86	7.81	0.194	0.183
Tembotrione 125 g a.i. ha^{-1} at 30 DAS	5260	5542	5899	6421	0.353	0.359	7.85	7.78	0.188	0.181
Atrazine 1 kg a.i. ha^{-1} (PE) followed by one hand weeding at 30 DAS	5498	5764	6064	6624	0.352	0.357	7.85	7.80	0.184	0.173
Atrazine (1 kg a.i. ha^{-1}, PE) followed by 2,4-D at 30 DAS (0.5 kg a.i ha^{-1})	5577	5875	6107	6737	0.353	0.360	7.85	7.80	0.181	0.173
Pendimethalin (1kg a.i. ha^{-1}, PE) followed by one hand weeding at 30 DAS	5392	5681	5998	6564	0.350	0.354	7.86	7.80	0.184	0.182
Weedy check	4465	4763	5131	5665	0.351	0.355	7.86	7.79	0.186	0.175
Weed free (hand weeding at 20 and 40DAS)	5656	5931	6182	6767	0.361	0.365	7.86	7.79	0.185	0.174
CD (p=0.05)	186	197	113	176	NS	NS	NS	NS	NS	NS
Initial value					0.359	0.356	7.90	7.80	0.186	0.176

Table 7: Effect of crop establishment methods and weed management practices on available nutrients in soil

Treatment	N(kg ha^{-1})		P(kg ha^{-1})		K(kg ha^{-1})		S(kg ha^{-1})		Zn (mg kg^{1})	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Crop establishment methods										
Ridge and furrow	199.9	202.7	16.8	19.7	231.6	234.7	16.0	16.2	0.554	0.555
Conventional flat bed	197.0	200.4	16.1	17.8	228.2	231.3	14.5	14.7	0.554	0.555
Raised-bed planting	201.9	204.4	17.6	19.1	234.8	236.6	16.2	16.8	0.563	0.564
CD (p=0.05)	3.51	4.10	1.42	1.12	4.18	4.86	1.51	1.98	0.006	0.004
Weed management practices										
Tembotrione 100 g a.i. ha^{-1} at 30 DAS	198.0	200.3	16.2	17.7	229.8	232.3	14.9	15.3	0.554	0.553
Tembotrione 125 g a.i. ha^{-1} at 30 DAS	198.8	200.8	16.6	18.5	230.4	233.9	15.8	16.0	0.56	0.561
Atrazine 1 kg a.i. ha^{-1} (PE) followed by one hand weeding at 30 DAS	200.4	203.9	17.0	18.9	232.0	234.9	15.1	16.3	0.555	0.555
Atrazine (1 kg a.i. ha^{-1}, PE) followed by 2,4-D at 30 DAS (0.5 kg a.i ha^{-1})	200.8	205.2	17.0	19.4	232.9	236.5	16.2	16.3	0.558	0.558
Pendimethalin (1kg a.i. ha^{-1}, PE) followed by one hand weeding at 30 DAS	198.9	201.9	16.7	18.6	230.5	234.2	15.9	16.1	0.561	0.562
Weedy check	196.8	199.5	16.5	18.4	230.3	230.5	14.8	15.0	0.539	0.544
Weed free (hand weeding at 20 and 40DAS)	202.4	205.6	17.4	20.6	234.4	237.0	16.7	16.6	0.573	0.575
CD (p=0.05)	1.60	2.38	1.02	0.84	3.54	4.12	1.43	1.64	0.004	0.003
Initial value	202.0	199.7	18.8	16.8	233.5	232.6	15.5	15.6	0.549	0.551

Available N, P, K, S and Zn in soil

The availability of N, P, K, S and Zn in soil was higher under raised bed planting and was closely followed by ridge and furrow sowing, which was significantly superior to conventional flat bed sowing during both the years (Table 6). This may be due to fact that raised bed planting lowered down the weed population and minimized the loss of nutrients by weeds, which resulted in increase in the availability of nutrients in soil.

All the weed management treatments recorded the highest N, P, K, S and Zn availability in soil than weedy check. Weed free had more N, P, K, S and Zn availability in soil, which was closely followed by sequential application of atrazine 1 kg ai. ha^{-1} (PE) followed by 2, 4-D at 30 DAS (0.5 kg ai. ha^{-1}, PoE), atrazine 1 kg ai. ha^{-1} followed by one hand weeding at 30 DAS and pendimethalin 1 kg ai. ha^{-1} (PE) followed by one hand weeding at 30 DAS, respectively. Whereas, weedy check had less N, P, K S, and Zn availability in soil due to higher weed dry weight and poor crop yield.

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