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Effect of weed management practices on nutrient content and their uptake by maize crop (*Zea mays* L.)

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Abstract
To evaluate the Effect of weed management practices on nutrient content and their uptake by maize crop (*Zea mays* L.), a field experiment was conducted during the *kharif* of 2023 at Research Farm of School of Agriculture, Abhilashi University, Chail Chowk, Mandi (H.P.). The field experiment was carried out in a randomized block design with three replications and eight treatments *viz*., T_1= Weedy check, T_2= Weed free, T_3= Atrazine @ 1.5 kg a.i. ha^{-1} (PE), T_4= Metribuzin @ 700 g a.i. ha^{-1} (PoE) (20 DAS) + One hand weeding (35 DAS), T_5= Topramezone @ 25 g a.i. ha^{-1} (PoE) (20 DAS), T_6= Atrazine @ 0.75 kg ha^{-1} (PE) + Pendimethalin @ 0.75 kg ha^{-1} (PE) *fb* 2,4-D @ 0.75 kg ha^{-1} (PoE) (35 DAS), T_7 = Twice hand weeding (20 and 45 DAS) and T_8= Straw mulching @ 5 t ha^{-1}. The various weed management practices showed the non-significant differences to content of nitrogen, phosphorus and potassium in grains and stover of the maize crop, however, the uptake of these nutrients was affected significantly by various weed management practices during field experiment.
Among the all weed management treatments, weed free (T_2) recorded maximum nitrogen, phosphorus and potassium content in grains and stover of maize crop, whereas, the statistical differences were non-significant. The weed free treatment (T_2) recorded significantly highest uptake of nitrogen, phosphorous and potassium by grains and stover as well as total uptake by maize crop, which was statistically at par with treatment T_6 [Atrazine @ 0.75 kg ha^{-1} (PE) + Pendimethalin @ 0.75 kg ha^{-1} (PE) *fb* 2,4-D @ 0.75 kg ha^{-1} (PoE) (35 DAS)] and T_7 [Twice hand weeding (20 and 45 DAS)]. However, the minimum nitrogen, phosphorous and potassium content in grains and stover and their uptake by maize crop was recorded under the treatment T_1 (Weedy check).

Keywords: Maize, atrazine, pendimethalin, topramezone, 2,4-D, nutrient content and uptake

Introduction
Maize is one of the most important cereal crop occupying third position in the world after wheat and rice. It is the most adaptable crop and it is produced in more than 166 nations world-wide, including tropical, subtropical and temperate region. In world, maize crop occupies an area of 202.92 million hectares with production of 1227.86 million metric tons and with a mean productivity of 6.05 metric tons ha^{-1} in the year of 2023-24 and China was the world leader in maize production, producing 288.84 million metric tons, followed by European Union, Africa, Ukraine, Russia and India (Anonymous, 2024a) [1]. In India, maize crop occupies an area 10.40 million hectare with production of 35.50 million metric tons with an average yield of 3.41 metric tons ha^{-1} (Anonymous, 2024b) [2]. Maize occupies important place as food (25%), animal feed (12%), poultry feed (49%), industrial products mainly starch (12%) and 1.0 per cent each in brewery and seed (Dass *et al.*, 2008) [3]. The maize crop required large amount of nitrogen, phosphorous and potassium in accumulation for its production. Weed management can increase fertilizer use efficiency of the crop with checking wasteful removal of nutrients by weeds. Successful maize production depends on the correct application of inputs that will sustain the environment as well as the agricultural production. These inputs are, adopted cultivars, plant population, soil tillage, fertilization, weed, insect and disease control, harvesting, marketing and finical resources (Kalhapure *et al.*, 2013) [4]. Amongst these production factors weed management plays a major role in increasing the productivity of maize (Barla *et al.*, 2016) [5]. Maize required unhindered nutrient during critical period assumes greater importance for

realising higher yield. Hence minimal weed interference should maintain for higher maize yield. According to Srividya *et al*., (2011) [6], weeds sprout quickly and gain a competitive edge over the crop during the first three to four weeks of maize's sluggish growth. When controlling weeds at the key time of crop weed competition, yield losses in maize resulting from weeds ranged from 28 to 100%, excluding environmental factors (Kumar *et al.*, 2017) [7]. In order to have a decent yield and profit, weed management is essential for all agricultural crops. Depending on the weed type, density, and surrounding conditions, different yield losses result from weeds. Weeds are estimated to cause up to 35% of the yield losses in maize crops (Hassan & Ahmed, 2005) [8].

Management of weeds is one of the most crucial factors for achieving higher productivity. In order to gain good economical yield of maize, weeds must be kept under check. Weeds can be control either by manually (Hand weeding and hoeing) and chemically by use of herbicides. Manual weeding is one of the effective methods to control weeds during the critical period. But timely weed management has become difficult due to unavailability of labour and escalating wages during peak period. Hence, herbicides are considered as alternative and effective weed control measure to implement in larger area then hand weeding. Chemical weed control (Herbicide) is quick, more effective, time and labour saving. Herbicides are substances that inhibit or completely eradicate weed growth in order to control weed development. Herbicides plays a significant and essential role in weed control strategies that produce large yields (Baghestani *et al*., 2005) [9]. Herbicides which can prevent weed infestation during the first 6 weeks, are very useful in maize crop. Due of their affordability and ease of use, herbicides gradually replacing hand weeding. However, certain weed species have become resistant to these chemicals as a result of repeated using a particular type of herbicide on the same area of land. Herbicides have different spectrums of weed control, which determine their effectiveness and use in the field. Therefore, there is great need to find out alternate weed management option. Chemical weed management by using of pre-emergence herbicides such as Atrazine and Pendimethalin has been found effective early stages of weed but, second flesh of weeds was controlled by post-emergence herbicide such as 2,4-D which may not be possible in manual or mechanical weeding due to its high cost of cultivation (Triveni *et al*., 2017) [10]. The application of pre-emergence of pendimethalin and atrazine in mixture with the post-emergence application of dicamba and 2,4-D provided the best control of weeds and result in higher grain yield (Bogdan *et al.*, 2004) [11]. Weedy check treatment may result in grain yield losses to the range of 28-100% of growth of maize crop (Das *et al.* 2012) [12] and the nutrient loss varies from 30-40% of the applied nutrients (Chopra and Angiras 2008) [13]. Moreover, continuous application of voluminous herbicide may affect the soil environment for sustain crop production applied herbicides are have fair impact to the health of soil. Keeping the above aspects in view, the current study was carried out to find out the Effect of various weed management practices on nutrient content and their uptake by maize crop.

Materials and Methods

The experiment was conducted at the Research Farm, School of Agriculture, Abhilashi University, Chail Chowk, Mandi (H.P.) during the *Kharif* of 2023. The experimental farm is located at 1391 meters above mean sea level, namely at latitude 300 32'N and longitude 740 53'E. The pH of the experimental soil was moderate acidic in reaction (5.80) with an electrical conductivity of 0.008 dSm^{-1}, medium in organic carbon (0.87%), low in nitrogen (252.17 kg ha^{-1}), low in phosphorus (6.78 kg ha^{-1}) and medium in potassium (250.59 kg ha^{-1}). The spacing for the tested variety (Hybrid corn 9220) was 60 × 20 cm for row to row and plant to plant. The field experiment was conducted in a randomized block design (RBD) with three replications and eight treatments *viz*., T_1= Weedy check, T_2= Weed free, T_3= Atrazine @ 1.5 kg a.i. ha^{-1} (PE), T_4= Metribuzin @ 700 g a.i. ha^{-1} (PoE) (20 DAS) + One hand weeding (35 DAS), T_5= Topramezone @ 25 g a.i. ha^{-1} (PoE) (20 DAS), T_6= Atrazine @ 0.75 kg ha^{-1} (PE) + Pendimethalin @ 0.75 kg ha^{-1} (PE) *fb* 2,4-D @ 0.75 kg ha^{-1} (PoE) (35 DAS), T_7= Twice hand weeding (20 and 45 DAS) and T_8= Straw mulching @ 5 t ha^{-1}. The recommended doses of herbicides were mixed with water and applied with knapsack sprayer. Fertilizer doses of nitrogen, phosphorous and potassium were applied through Urea (1/3rd), DAP and MOP as basal application and top dressing (Remaining amount of urea). The plant samples were collected after harvest from each treatment and cleaned and then shade-dried. In the subsequent step, the shade-dried samples were oven-dried at 60±50 °C for 24 to 48 hours until they reached a constant weight and then finely powdered using a mixture grinder. Based on the instruction described by (Jackson, 1973) [14], the nitrogen content in the plant sample was estimated using modified Kjeldahl digestion and distillation method. Phosphorus content was determined by using the venadomolybdate phosphoric yellow colour method and estimated using a spectrophotometer as described by (Jackson, 1973) [14]. Potassium content in plants was assessed by using a flame photometer (Jackson, 1973) [14]. In each treatment, grains and stover uptake of nitrogen, phosphorous and potassium was calculated by multiplying the nitrogen, phosphorous and potassium content (%) with yields of grains (q ha^{-1}) and stover (q ha^{-1}). As a result of summing up the uptake of nutrients by grains and stover of maize, the total uptake of nutrients was calculated.

Results and Discussion

Nitrogen content (%) and uptake (kg ha^{-1})

Data regarding to nitrogen content and their uptake by maize crop are presented in Table 1 and shown in Fig. 1. Analysis of the data showed non-significant difference in the content of nitrogen in grains and stover of maize crop due to different weed management practices. However, the uptake of nitrogen by grains, stover as well as total uptake of nitrogen were significantly influenced by different treatments of weed management practices of maize crop.

The highest nitrogen content in grains (1.30%) and stover (0.50%) of maize crop were recorded in the treatment T_2 (Weed free), whereas lowest nitrogen content in grains (1.21%) and stover (0.43%) were recoded under treatment T_1 (Weedy check), while, the statistical differences between various weed management practices found non-significant. However, the significantly maximum nitrogen uptake by grains (67.52 kg ha^{-1}) and stover (33.21 kg ha^{-1}) as well as total uptake (100.73 kg ha^{-1}) were noted under the treatment T_2 (Weed free) which was on par with treatment T_6 [Atrazine @ 0.75 kg ha^{-1} (PE) + Pendimethalin @ 0.75 kg ha^{-1} (PE) *fb* 2,4-D @ 0.75 kg ha^{-1} (PoE)] (64.15, 31.25 and 95.40 kg ha^{-1}, respectively) and T_7 [Twice hand weeding (20 and 45 DAS)] (62.11, 29.42 and 91.53 kg ha^{-1}, respectively). While the lowest nitrogen uptake by grains (28.30 kg ha^{-1}), stover (13.41 kg ha^{-1}) and total uptake of nitrogen (41.71 kg ha^{-1}) were found under the treatment T_1 (Weedy check) during field experiment.

Table 1: Effect of weed management practices on nitrogen content (%) and their uptake (kg ha^{-1}) by maize crop

S.N.	Treatments	Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})		
		Grains	Stover	Grains	Stover	Total
T_1	Weedy check	1.21	0.43	28.30	13.41	41.71
T_2	Weed free	1.30	0.50	67.52	33.21	100.73
T_3	Atrazine @ 1.5 kg a.i. ha^{-1} (PE)	1.21	0.45	49.02	19.75	68.77
T_4	Metribuzin @ 700 g a.i. ha^{-1} (PoE) (20 DAS) + One hand weeding (35 DAS)	1.27	0.48	59.62	26.49	86.11
T_5	Topramezone @ 25 g a.i. ha^{-1} (PoE) (20 DAS)	1.26	0.45	54.13	21.29	75.42
T_6	Atrazine @ 0.75 kg ha^{-1} (PE) + Pendimethalin @ 0.75 kg ha^{-1} (PE) *fb* 2,4-D @ 0.75 kg ha^{-1} (PoE) (35 DAS)	1.29	0.50	64.15	31.25	95.40
T_7	Twice hand weeding (20 and 45 DAS)	1.29	0.48	62.11	29.42	91.53
T_8	Straw mulching @ 5 t ha^{-1}	1.27	0.47	58.54	23.78	82.32
	SEm±	0.04	0.02	1.85	1.31	3.37
	CD (P= 0.05)	NS	NS	5.67	4.01	10.33

Weed free treatment recorded highest nitrogen content and their uptake by maize crop and this treatment was closely followed by application of some herbicides like- Atrazine, Pendimethalin (Pre-emergence), 2,4-D (Post-emergence) and Twice hand weeding at various stages of the maize crop. This might be due to the combinations of herbicides with hand weeding has showed the longer effect on controlling weed populations resulting in low crop-weed competition for nutrients and further leading to increasing the yields of the maize crop which ultimately may resulted in increase in nitrogen content and their uptake. Similar outcomes were reported by Chalka and Nepalia (2006) [15], Balyan and Kumpawat (2008) [16] and Kour *et al*., (2014) [17].

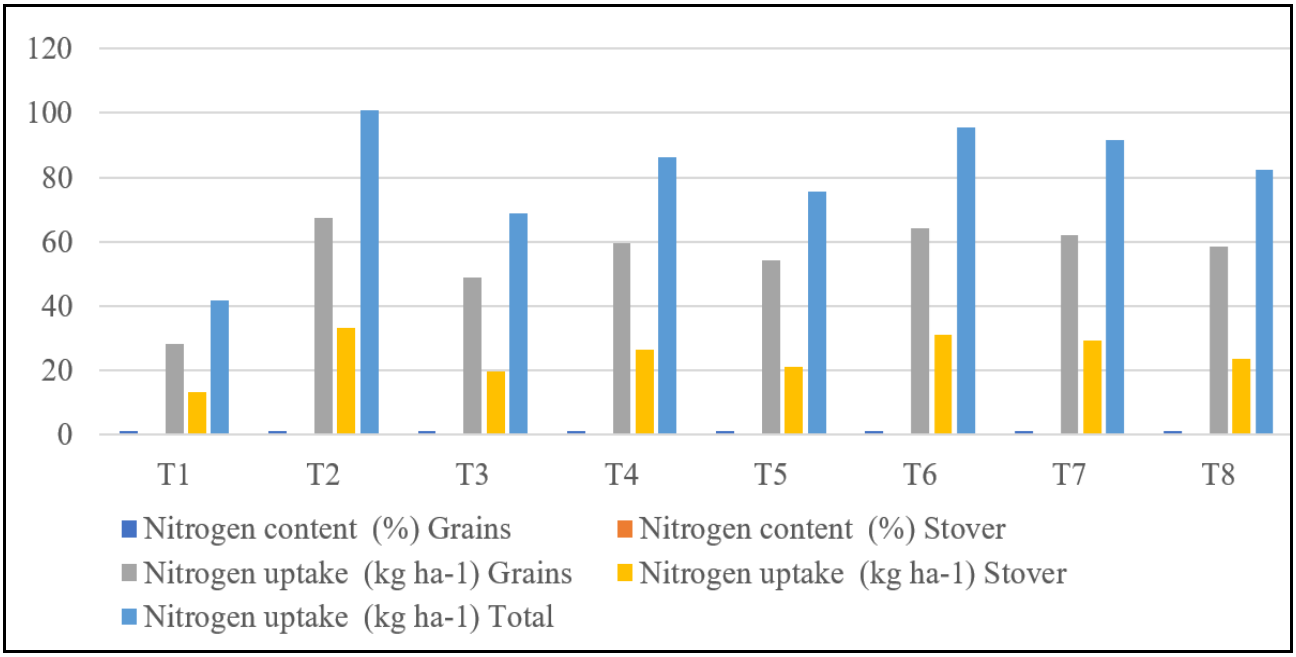

Fig 1: Effect of weed management practices on nitrogen content (%) and their uptake (kg ha^{-1}) by maize crop

Phosphorous content (%) and uptake (kg ha^{-1})

The phosphorous content of the maize crop is shown in Table-2 and displayed in Fig.-2, along with their uptake by grains, stover and total uptake. The study of data revealed that the content of phosphorous in grains and stover of maize crop were did not influenced significantly by the application of various weed management practices. However, the maximum phosphorous content in grains (0.25%) and stover (0.30%) of maize crop were observed under the treatment T_2 (Weed free), whereas, lowest phosphorous content in grains (0.20%) and stover (0.27%) were noted in the treatment T_1 (Weedy check).

However, different weed management practices showed the significant impact on the uptake of phosphorous by maize crop. Further analysis of the data revealed that the highest phosphorous uptake by grains (12.99 kg ha^{-1}) and stover (19.92 kg ha^{-1}) as well as total uptake of phosphorous (32.91 kg ha^{-1}) by maize crop was recorded in the treatment T_2 (Weed free) as compared to the rest of the treatments however, it was statistically at par with treatment T_6 [Atrazine @ 0.75 kg ha^{-1} (PE) + Pendimethalin @ 0.75 kg ha^{-1} (PE) *fb* 2,4-D @ 0.75 kg ha^{-1} (PoE)] (12.43, 18.12 and 30.55 kg ha^{-1}, respectively) and T_7 [Twice hand weeding (20 and 45 DAS)] (11.55, 17.77 and 29.32 kg ha^{-1}, respectively), while, the minimum phosphorous uptake by grains (4.68 kg ha^{-1}), stover (8.42 kg ha^{-1}) and total uptake of phosphorous (13.10 kg ha^{-1}) were noted under the treatment T_1 (Weedy check).

Table 2: Effect of weed management practices on phosphorous content (%) and their uptake (g ha^{-1}) by maize crop

S.N.	Treatments	Phosphorous content (%)		Phosphorous uptake (kg ha^{-1})		
		Grains	Stover	Grains	Stover	Total
T_1	Weedy check	0.20	0.27	4.68	8.42	13.10
T_2	Weed free	0.25	0.30	12.99	19.92	32.91
T_3	Atrazine @ 1.5 kg a.i. ha^{-1} (PE)	0.22	0.29	8.91	12.73	21.64
T_4	Metribuzin @ 700 g a.i. ha^{-1} (PoE) (20 DAS) + One hand weeding (35 DAS)	0.24	0.28	11.27	15.45	26.72
T_5	Topramezone @ 25 g a.i. ha^{-1} (PoE) (20 DAS)	0.23	0.28	9.88	13.25	23.13
T_6	Atrazine @ 0.75 kg ha^{-1} (PE) + Pendimethalin @ 0.75 kg ha^{-1} (PE) *fb* 2,4-D @ 0.75 kg ha^{-1} (PoE) (35 DAS)	0.25	0.29	12.43	18.12	30.55
T_7	Twice hand weeding (20 and 45 DAS)	0.24	0.29	11.55	17.77	29.32
T_8	Straw mulching @ 5 t ha^{-1}	0.24	0.28	11.06	14.16	25.22
	SEm±	0.01	0.02	0.52	0.72	1.24
	CD (P=0.05)	NS	NS	1.58	2.21	3.79

After applying weed free treatment, herbicides including Atrazine, Pendimethalin (Pre-emergence), 2,4-D (Post-emergence) and Twice-hand weeding the maize crop at different stages maize crop noted the maximum phosphorous content and uptake by the crop, which might be due to the result of using herbicides in conjunction with hand weeding, which has been shown to have a longer-lasting effect on weed population control. This reduces crop-weed competition for light, space and nutrients and raises maize crop yields, which might increase the phosphorous content and their uptake by maize crop. Similar outcomes were reported by Sharma and Gautam (2010) [18].

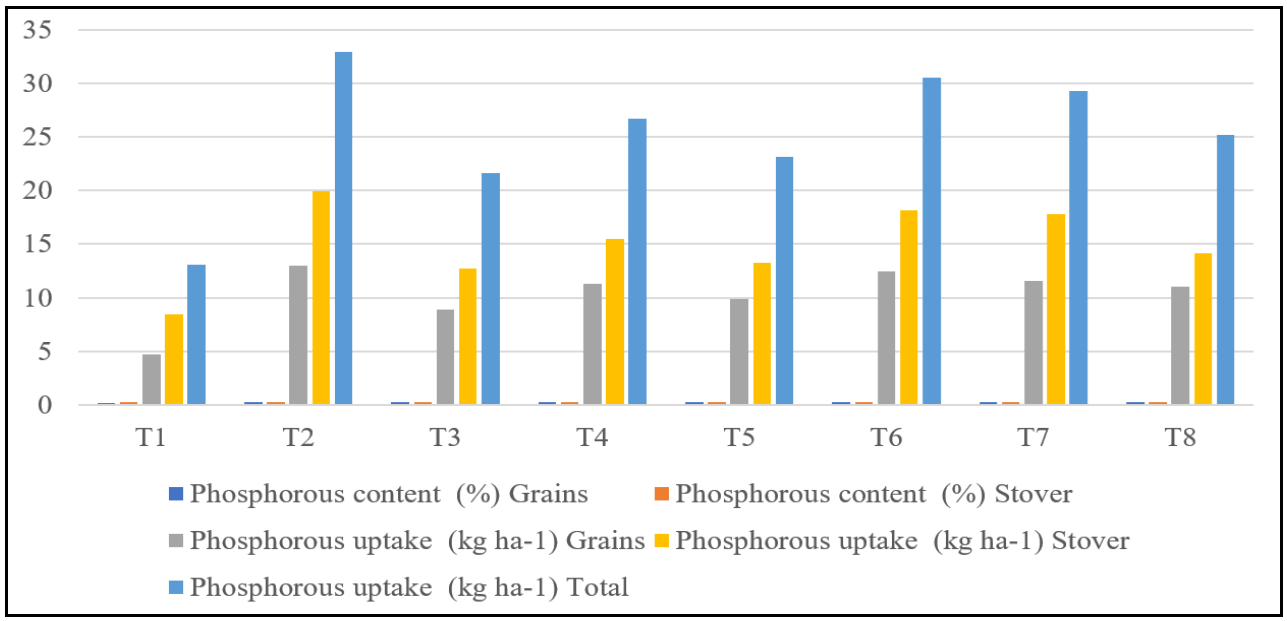

Fig 2: Effect of weed management practices on phosphorous content (%) and their uptake (kg ha^{-1}) by maize crop

Potassium content (%) and uptake (kg ha^{-1})

The potassium content and their uptake by grains and stover of maize crop is presented in Table-3 and illustrated in Fig. 3. The perusal of data showed that there was not any significant difference in the potassium content in maize grains and stover. While, the highest potassium content in grains (0.41%) and stover (1.22%) were recorded in the treatment T_2 (Weed free), whereas, lowest content in grain (0.34%) and stover (1.07%) of maize crop were found under the treatment T_1 (Weedy check).

However, the uptake of potassium by maize crop was significantly affected by different weed management practices. The highest value of potassium uptake by grains (21.29 kg ha^{-1}) and stover (81.04 kg ha^{-1}) as well as total uptake of potassium (102.33 kg ha^{-1}) was recorded under treatment T_2 (Weed free), which was on par with treatment T_6 [Atrazine @ 0.75 kg ha^{-1} (PE) + Pendimethalin @ 0.75 kg ha^{-1} (PE) *fb* 2,4-D @ 0.75 kg ha^{-1} (PoE)] (19.89, 75.62 and 95.17 kg ha^{-1}, respectively) and T_7 [Twice hand weeding (20 and 45 DAS)] (19.26, 74.17 and 93.43 kg ha^{-1}, respectively), whereas, the minimum potassium uptake by grains (7.95 kg ha^{-1}), stover (33.38 kg ha^{-1}) and total uptake of potassium (41.33 kg ha^{-1}) by maize crop were noted in the treatment T_1 (Weedy check).

Table 3: Effect of weed management practices on potassium content (%) and their uptake (kg ha^{-1}) by maize crop

S.N.	Treatments	Potassium content (%)		Potassium uptake (kg ha^{-1})		
		Grains	Stover	Grains	Stover	Total
T_1	Weed check	0.34	1.07	7.95	33.38	41.33
T_2	Weed free	0.41	1.22	21.29	81.04	102.33
T_3	Atrazine @ 1.5 kg a.i. ha^{-1} (PE)	0.36	1.11	14.58	48.72	63.30
T_4	Metribuzin @ 700 g a.i. ha^{-1} (PoE) (20 DAS) + One hand weeding (35 DAS)	0.40	1.18	18.78	65.13	83.91
T_5	Topramezone @ 25 g a.i. ha^{-1} (PoE) (20 DAS)	0.38	1.14	16.32	53.95	70.27
T_6	Atrazine @ 0.75 kg ha^{-1} (PE) + Pendimethalin @ 0.75 kg ha^{-1} (PE) *fb* 2,4-D @ 0.75 kg ha^{-1} (PoE) (35 DAS)	0.40	1.21	19.89	75.62	95.17
T_7	Twice hand weeding (20 and 45 DAS)	0.40	1.21	19.26	74.17	93.43
T_8	Straw mulching @ 5 t ha^{-1}	0.38	1.14	17.51	57.68	75.19
	SEm±	0.02	0.03	0.68	2.38	3.56
	CD (P=0.05)	NS	NS	2.07	7.29	10.90

The use of several herbicides, such as Atrazine, Pendimethalin (Pre-emergence), 2,4-D (Post-emergence), and Twice-hand weeding at different phases of the maize crop, closely followed the weed free treatment, which had the maximum potassium content and was most readily absorbed by the maize crop. This could be because applying herbicides in addition to hand weeding has demonstrated a longer-lasting effect on weed population control, reducing crop-weed competition for nutrients and ultimately raising maize crop yields, which could lead to an increase in potassium content and uptake. Same results were also reported by Chalka and Nepalia (2006) [15], Balyan and Kumpawat (2008) [16].

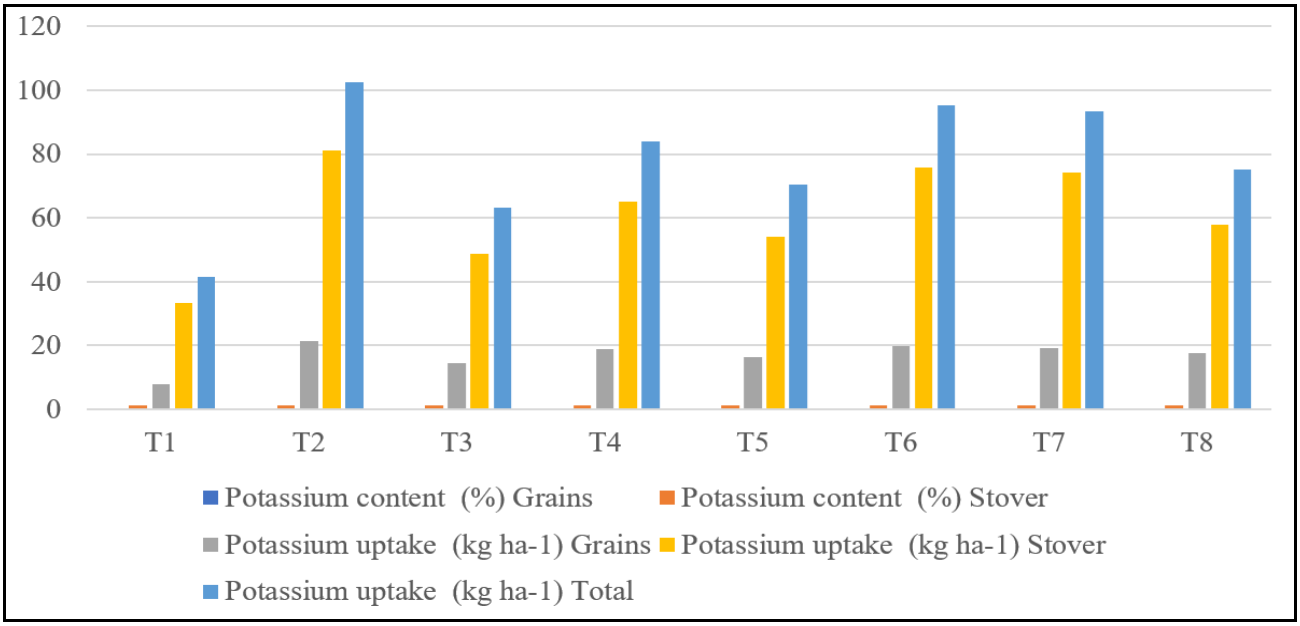

Fig 3: Effect of weed management practices on potassium content (%) and their uptake (kg ha^{-1}) by maize crop

Conclusion

This field study concluded that the nitrogen, phosphorous and potassium content in the grains and stover of the maize crop were did not influenced significantly by the application of different weed management practices during the field experiment. Whereas, the highest content of these nutrients in grains and stover of maize crop were found under weed free treatment (T_2). However, the uptake of nutrients by grains and stover as well as total uptake was varied significantly. The significantly maximum nitrogen, phosphorous and potassium uptake by grains and stover as well as total uptake by maize crop was recorded under treatment T_2 (Weed free) which was statistically at par with treatment T_6 [Atrazine @ 0.75 kg ha^{-1} (PE) + Pendimethalin @ 0.75 kg ha^{-1} (PE) *fb* 2,4- D @ 0.75 kg ha^{-1} (PoE)] and T_7 [Twice hand weeding (20 and 45 DAS)]. Whereas, the minimum uptake of nitrogen, phosphorus and potassium by grains, stover and total uptake by maize crop during experiment were found under treatment T_1 (Weedy check).

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