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Influence of weed management strategies on nutrient uptake and soil properties in fodder maize cultivation

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Abstract
A field experiment was conducted at the Research Farm, AICRP on Forage Crops, Department of Agronomy, JNKVV, Jabalpur (Madhya Pradesh) in 2019 to investigate the impact of various weed control methods on the concentrations of nitrogen, phosphorus, and potassium in maize biomass. The experiment utilized a randomized block design with three replications and ten treatments. These treatments included pre-emergence applications of atrazine at 1000 g/ha, pendimethalin at 750 g/ha, and a combination of atrazine at 750 g/ha with pendimethalin at 750 g/ha, as well as post-emergence applications of 2,4-D at 500 g/ha, tembotrione at 120 g/ha, and topramezone at 35 g/ha. Additionally, tembotrione at 120 g/ha with atrazine at 250 g/ha and topramezone at 35 g/ha with atrazine at 250 g/ha were tested, along with hand weeding twice at 20 and 40 DAS and a weedy check. The results showed that hand weeding at 20 and 40 DAS resulted in the highest uptake of nitrogen, phosphorus, and potassium by the crop, with values of 87.55 kg/ha, 55.59 kg/ha, and 127.85 kg/ha, respectively. This performance was comparable to the treatment of topramezone at 35 g/ha with atrazine at 250 g/ha, which recorded values of 83.22 kg/ha, 45.02 kg/ha, and 113.24 kg/ha for nitrogen, phosphorus, and potassium uptake, respectively, and tembotrione at 120 g/ha with atrazine at 250 g/ha, which recorded values of 78.81 kg/ha, 41.41 kg/ha, and 105.52 kg/ha for nitrogen, phosphorus, and potassium uptake, respectively.

Keywords: Atrazine, hand weeding, nutrient uptake, topramezone, tembotrione

Introduction
India holds a prominent position among maize-producing countries, ranking 4th globally in cultivated area and 7th in production, contributing around 4% of the world's area and 2% of total maize production (Sairam *et al*., 2023) [48-49]. A significant portion of maize production in India, roughly 47%, is allocated for poultry feed, while 13% serves as livestock feed and for human consumption each, with additional percentages utilized for industrial purposes, starch production, processed foods, and export (Raghuwanshi *et al*., 2023a; Yadav *et al*., 2023a) [43-44, 77-79]. Livestock play a crucial role in Indian agricultural systems, supporting and enhancing agriculture, with India feeding 17.5% of the world's population and 20% of the global cattle population on just 2.3% of the planet's land (Singh *et al*., 2022; Jha *et al*., 2023) [53, 22]. The annual growth rates of human and animal populations stand at 1.6% and 0.66%, respectively, resulting in increased competition for limited food and fodder resources (Yadav *et al*., 2023b; Verma *et al*., 2023) [78, 68, 69, 73]. Currently, only 4% of India's cultivable land is dedicated to fodder production, posing challenges in maximizing land utilization for high-quality animal feed (Kantwa *et al*., 2019; Yadav *et al*., 2023c; Singh *et al*., 2013b) [80, 79, 55]. The quantity and quality of fodder supplied to animals significantly impact their performance, further exacerbating the need for enhanced fodder production (Verma *et al*., 2016a; Patel *et al*., 2023) [74, 40]. Additionally, there exists a national shortage of concentrate feed ingredients, dry fodder, and green fodder, with limited opportunities to expand fodder cultivation areas (IGFRI Vision 2015; Singh *et al*., 2013a; Sahu *et al*., 2022) [11, 54, 55, 45].
Green fodder plays a crucial role in animal feeding under Indian circumstances (Tiwari *et al*., 2011a; Tomar *et al*., 2023a) [64, 65]. Maize (*Zea mays* L.) stands out as a favored fodder crop due to its high yield potential, adaptability to diverse climatic conditions, succulence, palatability,

and nutritional value (Kumar *et al*., 2022; Raghav *et al*., 2023) [26, 42]. The elemental composition of plants, including maize, is significantly influenced by many aspects such as genotype, climatic conditions, available nutrients, soil moisture, and aeration (Skowronska *et al*., 2010; Verma *et al*., 2022; Malviya *et al*., 2012) [57, 70, 72, 36]. The optimal mineral fertilization is crucial for achieving high-quality crop yields (Sahu *et al*., 2022; Swati *et al*., 2022) [45, 60]. N, P and K are essential plant nutrients, influencing various metabolic processes and overall plant health (Jha *et al*., 2011; Pahade *et al*., 2023) [19, 39]. Nitrogen, in particular, plays a pivotal role in plant metabolism and protein synthesis, with its perishable nature (Stoyanov *et al*., 1996b; Verma *et al*., 2023) [58, 68, 69, 73]. Potassium and phosphorus enhance plants' resilience against various stressors, further contributing to crop productivity (Mengel *et al*., 2001; Kumhar *et al*., 2022; Kumbhare *et al*., 2023; Sahu *et al*., 2023; Patidar *et al*., 2023) [37, 32, 46-47, 35]. Our study aimed to evaluate the effect of different treatments on the macroelement content (nitrogen, phosphorus, and potassium) of maize plant biomass during field experimentation.

Methodology

During the 2019 *Kharif* season, a field experiment was conducted at the Research Farm, AICRP on Forage Crops, Department of Agronomy, JNKVV, Jabalpur (Madhya Pradesh). The soil of the experimental area had a neutral pH (7.21) and low organic carbon content (0.54%), with medium levels of available N (231.56 kg/ha), P (16.59 kg/ha), and K (313.66 kg/ha), along with normal electrical conductivity (0.33). Ten treatments were taken in a randomized block design, replicated thrice. These treatments included pre-emergence applications of atrazine at 1000 g/ha, pendimethalin at 750 g/ha, and a combination of atrazine at 750 g/ha with pendimethalin at 750 g/ha, as well as post-emergence applications of 2,4-D at 500 g/ha, tembotrione at 120 g/ha, and topramezone at 35 g/ha alone. Additionally, combinations of tembotrione at 120 g/ha with atrazine at 250 g/ha and topramezone at 35 g/ha with atrazine at 250 g/ha were tested, along with hand weeding twice at 20 and 40 days after sowing (DAS) and a weedy check. All plots applied a dose of 80 kg/ha of nitrogen, 40 kg/ha of P_2O_5, and 20 kg/ha of K_2O. Nitrogen was given half at sowing and the rest was top-dressed at 25 DAS and 45 DAS.

Upon harvesting the maize crop, stover samples were meticulously collected and subjected to thorough analysis. The samples were dried until reaching a constant weight and then finely ground into powder form. Nitrogen, phosphorus, and potassium contents were meticulously determined through established methodologies: nitrogen using the micro-Kjeldahl digestion method (AOAC, 1966) [1], phosphorus via the Vanadomolybdo phosphoric acid yellow color method (AOAC, 1966) [1], and potassium through flame photometer method (Khanna *et al.*, 1971) [25].

Furthermore, to assess the impact of the various treatments on soil chemical properties, soil samples were diligently collected from each plot post-harvest. These samples were carefully labeled and combined based on treatment replication. After thorough drying, the soil samples were ground into powder and sieved to ensure uniformity. Subsequently, they underwent a battery of chemical analyses following standardized procedures. Organic carbon content was assessed using the Walkey and Black rapid titration method (Walkley and Black 1934) [76], available nitrogen via the alkaline permanganate method (Subbiah and Asija 1956) [59], available phosphorus using the calorimetric method (Olsen *et al.*, 1954) [38], and available potassium through flame photometer (Hanway and Heidal 1953) [10], soil pH through a glass electrode pH meter (Piper 1967) [48] and Electrical conductivity was measured using Solubridge method (Black 1965) [6].

The data collected from both the stover and soil analyses were meticulously compiled and interpreted to glean valuable insights into the effects of the different treatments on nutrient uptake, crop yield, and soil health. These findings hold significant implications for optimizing weed control strategies and enhancing agricultural productivity in maize cultivation systems.

Results and Discussion

Nutrients uptake

Treatments for weed management had a considerable impact on the nitrogen, phosphorus, and potassium uptake by fodder maize. Table 1 provides information on stover's nutrient concentration and uptake.

Nitrogen uptake

The highest uptake of nitrogen by the crop was found under hand weeding, reaching 87.55 kg/ha. This was closely followed by treatments including topramezone at 35 g/ha + atrazine at 250 g/ha (83.22 kg/ha), tembotrione at 120 g/ha + atrazine at 250 g/ha (78.81 kg/ha), tembotrione at 120 g/ha (68.78 kg/ha), and topramezone at 35 g/ha (65.58 kg/ha). These five treatments exhibited statistically similar nitrogen uptake and showed higher values compared to other treatments. However, they notably outperformed 2,4-D at 500 g/ha (52.92 kg/ha), atrazine at 750 g/ha + pendimethalin at 750 g/ha (46.11 kg/ha), and atrazine at 1000 g/ha (40.93 kg/ha), which demonstrated equivalent performance (Malviya, *et al*., 2012 Jha *et al*., 2007 Pahade *et al*., 2023 and Tomar *et al*., 2023) [36, 66, 39, 66]. The lowest nitrogen uptake was recorded for pendimethalin at 750 g/ha (36.61 kg/ha), with the absolute lowest uptake observed in the weedy check plot at 30.69 kg/ha in maize (Kewat *et al*., 2009) [24]. Previous studies by Sinodiya and Jha (2014) [56], Jha and Kewat (2013) [17, 20], Tiwari *et al.* (2013) [63], and Tiwari *et al.* (2011a) [64] have also recorded that nutrient uptake by crops is minimal under weedy check conditions, likely due to heightened competition between crops and weeds for nitrogen, phosphorus, and potassium.

Uptake of phosphorus

The highest phosphorus uptake by the crop occurred under hand weeding at 20 and 40 days after sowing (DAS), reaching 55.59 kg/ha. This was closely followed by treatments including topramezone at 35 g/ha + atrazine at 250 g/ha (45.02 kg/ha), tembotrione at 120 g/ha + atrazine at 250 g/ha (41.41 kg/ha), topramezone at 35 g/ha (35.88 kg/ha), and tembotrione at 120 g/ha (31.94 kg/ha). All values were statistically similar and exhibited higher phosphorus uptake compared to other treatments, namely 2,4-D at 500 g/ha (20.45 kg/ha), atrazine at 750 g/ha + pendimethalin at 750 g/ha (22.46 kg/ha), and atrazine at 1000 g/ha (15.49 kg/ha). The lowest phosphorus uptake was found with pendimethalin at 750 g/ha (16.15 kg/ha), with the absolute lowest phosphorus uptake observed in the weedy check plot at 12.47 kg/ha in maize (Kumar *et al*., 2023 and Shri *et al*., 2014) [27, 52]. Previous studies by Jha and Soni (2011) [19] and Verma *et al*. (2023) [68, 69, 73] have also reported that nutrient uptake by crops is lowest under weedy check conditions, likely due to increased competition between crops and weeds for nitrogen, phosphorus, and potassium.

Table 1: Effect of various treatments on N, P, K (%) contents and total uptake of nutrients in fodder maize

Treatments		N, P, K content in maize biomass			Total uptake (kg/ha)		
		N (%)	P (%)	K (%)	N	P	K
T_1	Tembotrione 34.4% SC	0.56	0.26	0.86	68.78	31.94	105.63
T_2	Topramezone 33.6% SC	0.53	0.29	0.89	65.58	35.88	110.13
T_3	Atrazine 50% WP	0.37	0.14	0.55	40.93	15.49	60.84
T_4	Pendimethalin 38.7% EC	0.34	0.15	0.49	36.61	16.15	52.77
T_5	Tembotrione 34.4% SC +Atrazine 50% WP	0.59	0.31	0.79	78.81	41.41	105.52
T_6	Topramezone 33.6% SC + Atrazine 50% WP	0.61	0.33	0.83	83.22	45.02	113.24
T_7	Atrazine 50%WP + Pendimethalin 38.7% EC	0.39	0.19	0.69	46.11	22.46	81.58
T_8	2, 4-D 38%	0.44	0.17	0.67	52.92	20.45	80.58
T_9	Hand weeding	0.63	0.4	0.92	87.55	55.59	127.85
T_{10}	Weedy Check	0.32	0.13	0.33	30.69	12.47	31.65
CD at 5%		0.03	0.05	0.05	2.56	1.23	3.58

Uptake of potassium

The highest uptake of potassium by the crop was observed during hand weeding, reaching 127.85 kg/ha. Following closely were treatments including topramezone at 35 g/ha + atrazine at 250 g/ha (113.24 kg/ha), tembotrione at 120 g/ha + atrazine at 250 g/ha (105.52 kg/ha), topramezone at 35 g/ha (110.13 kg/ha), and tembotrione at 120 g/ha (105.63 kg/ha). These five treatments exhibited statistically similar results, demonstrating higher potassium uptake compared to other methods (Verma *et al.* 2016 a and b) [74, 75]. However, they notably outperformed 2,4-D at 500 g/ha (80.58 kg/ha), atrazine at 750 g/ha + pendimethalin at 750 g/ha (81.58 kg/ha), and atrazine at 1000 g/ha (60.84 kg/ha), which showed similar outcomes. The lowest potassium uptake was recorded for pendimethalin at 750 g/ha (52.77 kg/ha), with the absolute minimum of 31.65 kg/ha observed in the weedy check plot in maize. Sanodiya *et al.* (2013) [50], Verma *et al.* (2022) [70, 72], Kantwa *et al.* (2019) [80], Jha *et al.* (2007) and Kumbhare *et al.*, 2023 also noted in their study that crop nutrient uptake was at its lowest when grown under weedy check conditions, potentially due to heightened competition between crops and weeds for nitrogen, phosphorus, and potassium.

Changes in chemical properties of soil

Alterations in the chemical composition of the soil, such as soil pH, electrical conductivity (EC), organic carbon (OC), and the availability of nitrogen (N), phosphorus (P), and potassium (K), did not exhibit significant fluctuations following the harvesting of Kharif crops across any of the treatments when compared to their initial levels (Table 2).

Table 2: Effect of various treatments on soil properties

Treatments		PH	EC (Ds/ mol)	Organic Carbon (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
T_1	Tembotrione 34.4% SC	7.38	0.41	0.60	232.15	16.88	331.58
T_2	Topramezone 33.6% SC	7.38	0.42	0.62	235.92	17.30	334.46
T_3	Atrazine 50% WP	7.40	0.40	0.61	233.41	16.74	330.24
T_4	Pendimethalin 38.7% EC	7.40	0.40	0.60	233.15	16.77	331.12
T_5	Tembotrione 34.4% SC +Atrazine 50% WP	7.44	0.44	0.63	236.54	17.30	335.25
T_6	Topramezone 33.6% SC + Atrazine 50% WP	7.37	0.41	0.62	235.36	17.27	334.55
T_7	Atrazine 50%WP + Pendimethalin 38.7% EC	7.40	0.40	0.61	233.14	16.56	332.12
T_8	2, 4-D 38%	7.41	0.41	0.62	235.25	17.12	333.25
T_9	Hand weeding	7.43	0.44	0.62	236.44	17.21	335.11
T_{10}	Weedy Check	7.41	0.40	0.60	233.32	16.48	329.85
Initial		7.21	0.33	0.54	231.56	16.59	328.56

Conclusion

The study revealed significant variations in N, P, K uptake by crops under various weed management treatments. The highest N, P, K uptake was recorded during hand weeding, closely followed by specific herbicide treatments, including topramezone @ 35 g ha^{-1} + atrazine @ 250 g ha^{-1} and tembotrione @ 120 g ha^{-1} + atrazine @ 250 g ha^{-1}. These top-performing treatments demonstrated statistically similar and notably higher N, P, K uptake compared to other treatments, highlighting their effectiveness in enhancing nutrient uptake by crops.

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