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Impact of weed management methods on growth, productivity and economics of spring maize under north-western Indo-Gangetic plains of India

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ABSTRACT

This study focuses on different weed management methods and their impact on the growth, productivity, and economics of spring maize. The experiment was conducted in RBD with twelve weed management methods replicated thrice. Treatments consisted of T1:Weedy check, T2: Weed-free check, T3: Weed-free (2 hoeing at 15 and 30 DAS), T4: Lay by application of Atrazine (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS, T5: Lay by application of Pendimethalin (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS, T6:Halosulfuron @ 67.5 g ha^{-1} at 2-3 leaf stage, T7:Tembotrione @ 120 g ha^{-1} at 2-3 leaf stage, T8: Atrazine (0.75 kg a.i ha^{-1}) as pre-emergence + Halosulfuron @ 67.5 g ha^{-1} at 25 DAS, T9: Atrazine (0.75 kg a.i ha^{-1}) as pre-emergence + Tembotrione @ 120 g ha^{-1} at 25 DAS, T10: Maize + rice crop residue as mulch and hand pulling of weeds at 25 DAS, T11:Topramezone (25.2 g ha^{-1}) as post-emergence and T12: CRIJAF nail weeder at 6 days after emergence and 20 days after emergence. Experimental results indicated that crop growth and development, and productivity were maximum in weed free up to maturity followed by weed free by two hoeing at 15 and 30 DAS. Lay by application of Atrazine (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS enhanced plant height by 6.2 - 7.9 percent, plant dry matter by 5.8 - 7.9 percent, Chlorophyll index by 15.6 - 22.4 percent, grain yield by 10.9-14.2 percent and biological yield by 5.5-7.0 percent. The highest Net return and B-C ratio were found in weed-free check followed by two hoeings, lay by application of atrazine and pendimethalin.

***Key words:** CRIJAF, Chlorophyll index, Hoeing, Post-emergence, Productivity, Lay by application, Weed-free*

Introduction

The greatest method for effectively managing weeds is integrated weed management. With this in mind, an RBD experiment with 12 treatments and three replications was designed. The growth development parameters (plant height, plant dry matter accumulation, leaf area index), physiological parameters (CGR, Chlorophyll index), grain yield, biological yield were significantly influenced by different weed management strategies. The highest values of all agro-physiological attributes and yield were found in weed free treatment (full season, two hoeing). But lay by application of herbicides (atrazine and pendimethalin) better performed than herbicide combinations and single dosage. Lowest values were found in weedy treatment. The present study was concluded that weed free at critical stage (two hoeing at 20 and 40 DAS; CRIJAF nail weeder at 15 and 30 DAS) were superior and lay by application of herbicides (atrazine and pendimethalin) and combination application of herbicide i.e., Atrazine (0.75 kg ha^{-1}) as PE + Halosulfuron (67.5 g ha^{-1}) as PoE and atrazine (0.75 kg ha^{-1}) + Tembotrione (120 g ha^{-1}) as PoE better performer than single dose application of herbicides (halosulfuron, topramezone, tembotrione).

Maize (*Zea mays* L.) is one of the most important cereal crops grown over diverse environment and geographical ranges for human food, feed and fodder for livestock and raw materials for industries. In India maize on an average is cultivated in about 7.42 M ha producing 14.72 MT of grain having an average productivity around 19 q ha^{-1}. Being a C4 plant, it is capable of utilizing solar radiation more efficiently than several other cereal crops (Deewan *et al*. 2017). Maize plants grow quicker than other plants in bright sunlight and warm temperatures. C4 plants use C4 carbon fixation pathways, which reduce photorespiration and boost photosynthetic efficiency. There are 3 distinct seasons for cultivation of maize in India: 1) kharif 2) rabi-in peninsular India and Bihar 3) spring-in North India.

Maize is a wide-spaced row crop with a sluggish growth rate, which provides many opportunities for weed emergence and growth, especially in the early phases of growth. *Acrachne racemose, Dactyloctenium aegyptiacum, Commelina benghalensis, Eragrostistenella, Digitariasanguinalis, Echinochloacolona, Trianthemaportulacastrum, Phyllanthus niruri, Euphorbia hirta, Euphorbia microphylla, Digera arvensis, Amaranthus viridis, Cyperus rotundus, Cyperus compressus, Cynodondactylon. Elusine indica*, etc. are major weeds of maize in Punjab region and *Celosia argentea, C. benghalensis, D. aegyptium, D. arvensis, E. indica, E. colona, Corchorus trilocularis, Leptochloa chinensis* and *Rumex acetosella* are dominant weed floraat Delhi (Singh *et al*., 2012). These weeds compete forcedly with the crop, consuming the lion's share of nutrients, moisture, and light, resulting in poor growth and development, resulting in low yields. Weeds alone account for one-third of the total estimated output losses caused by pests, insects, illnesses, and weeds around the world. Weeds are the most significant yield-reducing variables in maize production in India. Weed infestation in maize is fairly common, and it usually results in a significant drop in yield, especially in dry land conditions (Sulewska *et al.* 2012).

Weeds can be controlled by adapting mechanical/physical, cultural, biological and chemical method. Many farmers manually control weeds in maize. Manual method takes a lot of time and effort, (Vissoh *et al.,* 2004). But effective management of weeds by two manual hoeing at CPCWC stage. Utilization of previous year crop residue as a mulch which is improves soil physical, chemical and biological activity. Crop residue mulching can moderate soil temperature and moisture content (Li *et al*., 1999) and directly alter crop productivity. After decomposition of organic mulches, such as straw mulching, increases soil organic matter, biological activity, and boost plant nutrients.

Timely non-availability and high labor cost and some weeds grow later in the season, after the CPWC has ended promotes farmer towards chemical method. Chemicals are more efficient in maize field because they can control weeds before they emerge, kill both vegetative and deep-rooted weeds, and are also more cost-effective and faster result (Chikoye *et al.,* 2005). Weed emergence pattern, application timing and crop growth stages are most important for better performance of herbicides. Use of chemical herbicides like Atrazine and pendimethalin as pre-emergence effectively controls broad leaved weeds and some annual grasses. Post emergence application of atrazine, halosulfuron and tembotrione also operational in field. Continues application of same herbicides on same crop and same field, weeds show resistance to it. So, in this concern combination of herbicides with mechanical and cultural method is most effective and cost reliable. Lay by application of post emergence herbicides after one hoeing is one of the good examples to this method. Combination of two herbicides like application of pre-emergence and later application of post emergence also controls grassy and non-grassy weeds effectively. Utilizing manual techniques, hoeing, mulching, and lower herbicide dose minimize residual toxicity in succeeding crops while providing broad spectrum weed control at cheaper cost (Pandey and Ved-Prakash, 2002; Meyyappan and Kathiresan, 2005). Less work done on this concept in spring maize to this region. Concerning the above facts, the current investigation was framed with an objective- impact of different weed management methods on growth and productivity of spring maize and workout the economics of different weed management strategies.

Materials and Method

Experimental site

The experiment was carried out in the spring of 2022 atexperimental farm lovely professional university Jalandhar, Punjab. This field has an average elevation of 252m MSL and is located at 310 22231.81 North Latitude and 750 23203.02 East Longitude. The annual precipitation in this area is 703 mm having cold winters, scorching summers, and a distinct rainy season. Even during the coldest months of the year, from December to January, the temperature never drops below zero degrees, with the lowest ranging between 4 and 10 degrees Celsius. Rarely, the peak summer time temperature rises from 45 to 48 degrees Celsius between mid-May and mid-June, while the average summertime temperature stays between 35 and 45 degree celsius.

Treatment details

The experiment was arranged with Randomized Block Design (RBD) with 12 treatments and replicated thrice viz., T1:Control (weedy check), T2: Weed free check (full duration), T3: Weed free (2 hoeing at 15 and 30 DAS),T4: Lay by application of Atrazine (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS, T5: Lay by application of Pendimethalin (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS, T6:Halosulfuron @ 67.5 g ha^{-1} at 2-3 leaf stage, T7:Tembotrione @ 120 g ha^{-1} at 2-3 leaf stage, T8: Atrazine (0.75 kg a.i ha^{-1}) as pre-emergence + Halosulfuron @ 67.5 g ha^{-1} at 25 DAS, T9: Atrazine (0.75 kg a.i ha^{-1}) as pre-emergence + Tembotrione @ 120 g ha^{-1} at 25 DAS, T10: Maize + rice crop residue as mulch and hand pulling of weeds at 25 DAS, T11:Topramezone (25.2 g ha^{-1}) as post-emergence and T12: CRIJAF nail weeder at 6 days after emergence and 20 days after emergence.

The maize variety PMH-10 was used and sown with spacing of 60 × 20 cm. The recommended fertilizer (120: 60: 40 NPK kg ha^{-1}) was applied. The full doses of phosphorus, potassium, and 50% of the nitrogen were applied at the time of sowing, and the remaining 50% of the nitrogen was applied in two splits, one at knee height and the other at tasseling stage.

Statistical investigation

Analysis of variance (ANOVA) was performed to determine the effect of different treatments of weed management methods growth and productivity of maize. SPSS window version 21.0 (SPSS Inc., Chicago, IL, USA) was used for the statistical analysis of the data. The least square difference (LSD) was performed Duncan's multiple range test (DMRT) in order to find the significant difference of all of the data with a level of significance at $p \leq 0.05$.

Results and Discussion

Plant height

Weed management methods on plant height of spring maize were significantly ($p \leq 0.05$, Table 1) influenced during 2022. Weed free until harvest of the crop and weed free by two hoeing at 15 and 30 DAS achieved maximum plant height (10.20 - 10.40 cm). Lay by application of Atrazine (0.75kga.i/ha) after one hoeing at 15 to 20DAS enhanced plant height by 6.2 - 7.9 percent which was statistically at par with Lay by application of Pendimethalin (0.75 kga.i ha^{-1}) after one hoeing at 15 to 20 DAS. Similarly, Atra-

Table 1. Effect of weed management methods on plant height and dry matter accumulation of spring maize during 2022.

Treatment	Plant height				Dry matter accumulation			
	30 DAS	60 DAS	90 DAS	Maturity	30 DAS	60 DAS	90 DAS	Maturity
T1	5.91f	40.07d	117.33e	146.68e	36.00cd	120.00e	157.50e	175.30e
T2	10.40a	90.20a	172.50a	180.80a	39.95abcd	168.00a	215.60a	242.60a
T3	10.20ab	88.06a	169.70ab	177.50a	45.50abcd	164.00a	208.40a	237.30a
T4	9.33bc	72.67b	155.63abc	166.40b	51.93a	150.00b	194.20b	223.40b
T5	8.55cd	61.43bc	145.57bcd	160.39c	46.31abcd	140.00c	184.30c	213.50c
T6	6.39f	42.23d	120.50de	149.20e	43.00abcd	122.00e	166.20d	192.30d
T7	6.68f	44.33d	121.70de	150.20de	33.47d	123.00e	168.20d	195.30d
T8	8.42d	59.04c	143.23bcd	159.30c	50.00ab	136.00cd	180.40c	207.30c
T9	8.50cd	60.90bc	144.30bcd	160.20c	49.15abc	138.00cd	182.70c	210.20c
T10	9.41b	73.90b	157.03abc	169.50b	46.33abcd	152.00b	196.10b	225.30b
T11	7.56e	57.33c	141.57cde	155.40cd	36.39bcd	133.00d	178.30c	205.30c
T12	9.50b	74.75b	158.60abc	170.07b	48.36abc	154.00b	198.30b	227.30b

Note: The values within columns with different letters differed significantly with each other.

zine (0.75 kga.i ha^{-1}) as pre-emergence + Tembotrione (120 gha^{-1}) at 25 DAS enhanced plant height by 9.7 - 11.3 percent. However, the lowest plant height was found in weedy check over weed-free until maturity and weed free by two hoeing. The similar pattern continued at 60, 90 DAS, and at maturity. Triveni *et al.* (2017) reported that significantly maximum plant height was found in hand weeding twice at 20 and 40 DAS. Similar results were also revealed by Barad *et al.* (2016) and Fayaz *et al.* (2019).

Plant dry matter accumulation

Plant dry matter of spring maize was considerably (Table 1) impacted by weed management practices in 2022. Weed-free until the harvest of the crop and weed free by two hoeing at 15 and 30 DAS achieved maximum plant dry matter (164.0- 168.0 g). Lay by application of Atrazine (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS enhanced plant dry matter by 5.8 - 7.9 percent which was statistically at par with Lay by application of Pendimethalin (0.75kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS. Similarly, Atrazine (0.75 kg a.i ha^{-1}) as pre-emergence + Tembotrione (120 g ha^{-1}) at 25 DAS enhanced plant dry matter by 11.4 - 13.3 percent over weed free up to maturity and weed free by two hoeing.However, the lowest plant dry matter was found in weedy check. Sharma and Sharma and Rayamajhi, (2022) reported that higher plant biomass less weed population was found in hand weeding at 15 and 20 DAS followed by Atrazine (pre-emergence) and Tembotrione (post emergence). Taller plant height and broader leaf area might be increased plant drymatter accumulationin weed control treatments (Walia *et al.*, 2007 and Kandasamy, 2018). Similar results found by Ehsas *et al.* (2016) and Barad *et al*. (2016).

Leaf area index

Weed management methods on leaf area index of spring maize were significantly (p≤ 0.05, Table 2) influenced during 2022. Weed-free until the harvest of the crop and weed free by two hoeing at 15 and 30 DAS achieved maximum leaf area index (0.25-0.28). Lay by application of Atrazine (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS enhanced leaf area index by 5.6-7.3 percent which was statistically at par with Lay by application of Pendimethalin (0.75kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS. Similarly, Atrazine (0.75 kg a.i ha^{-1}) as pre-emergence + Tembotrione @ 120 g ha^{-1} at 25 DAS enhanced leaf area index by 9.7-11.3 percent over weed free up to maturity and weed free by two hoeing. Leaf area and leaf area index, which are strongly related to photosynthesis and transpiration, are widely employed as characteristic metrics for monitoring crop growth and projecting crop yield. These findings are correlated with Kumawat *et al*. (2021), Rasool *et al.* (2016) and Ghodralollah *et al.* (2005). However, the lowest leaf area index was found in weedy check. This might be due to more crop weed competition for nutrients, moisture etc. (Jaybhaye *et al*., 2020).

Table 2. Effect of weed management methods on leaf area index, crop growth rate, SPAD, grain and biological yield of spring maize during 2022.

Treatment	Leaf area index		Crop growth rate (g^{-2} day^{-1})		SPAD		Grain yield (q ha^{-1})	Biological yield (q ha^{-1})
	30 DAS	60 DAS	0-30 DAS	30-60 DAS	30 DAS	60 DAS		
T1	0.10l	1.60f	10.00cd	23.33de	18.20g	20.50h	38.33d	188.4e
T2	0.28a	2.94a	11.10abcd	35.57a	26.80a	34.50a	63.17a	243.7a
T3	0.25b	2.88a	12.64abcd	32.92ab	24.20b	31.70b	60.83a	239.9a
T4	0.19e	2.71bc	14.43a	27.24cd	22.56c	26.80d	54.17bc	226.5b
T5	0.17f	2.60bcd	12.86abcd	26.03cde	21.40d	24.80e	54.05bc	216.4c
T6	0.11k	2.41e	11.95abcd	21.94e	19.05f	21.58gh	49.56c	199.1d
T7	0.12j	2.40e	9.30d	24.87de	19.12f	21.90g	50.08bc	201.4d
T8	0.15h	2.58cd	13.89ab	23.89de	21.14d	24.13ef	53.17bc	214.6c
T9	0.16g	2.59cd	13.65abc	24.68de	21.25d	24.56e	53.23bc	215.1c
T10	0.21d	2.74b	12.87abcd	29.35bc	23.10c	28.12c	54.48b	228.6b
T11	0.14i	2.52de	10.11bcd	26.84cd	20.10e	23.40f	50.9bc	212.3c
T12	0.22c	2.74b	13.43abc	29.34bc	23.25c	28.40c	54.67b	229.5b

Note: The values within columns with different letters differed significantly with each other.

Crop growth rate Weed management methods on crop growth rate of spring maize were significantly ($p \leq 0.05$, Table 2) influenced during 2022. There were non-significant results were found for crop growth rate at 0-30 DAS. Later, growth stages showed significant effect. Weed free up to harvest (35.57 g m^{-2} day^{-1}) gave significantly higher relative growth rate followed by weed free by two hoeing at 15 and 30 DAS, CRIJAF nail weeder at 6 and 20 DAE, Maize + rice crop residue as mulch and hand pulling of weeds at 25 DAS (32.92- 29.34 g m^{-2} day^{-1}). Among the chemical application treatments lay by application of atrazine (0.75 $kgha^{-1}$) after one hoeing at 15 to 20 DAS, lay by application of pendimethalin (0.75 $kgha^{-1}$) after one hoeing at 15 to 20 DAS, Atrazine (0.75 $kgha^{-1}$) as PE + Tembotrione (120 gha^{-1}) at 25 DAS, Atrazine (0.75 $kgha^{-1}$) as PE + Halosulfuron (67.5 $kgha^{-1}$) at 25 DAS (23.89-27.24 g m^{-2} day^{-1}) and these treatments are statistically similar. The lowest crop growth rate was found in weedy check (23.33 g m^{-2} day^{-1}). The same trend was followed at 60-90 and 90-120 DAS. Same results were found by Gupta *et al.* (2017) and Mahmood *et al*. (2016).

Chlorophyll index (SPAD)

Chlorophyll index of spring maize was considerably (Table 2) impacted by weed management methods in 2022. Weed-free until the harvest of the crop and weed free by two hoeing at 15 and 30 DAS achieved maximum chlorophyll index (24.20 - 26.80). Lay by application of Atrazine (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS enhanced Chlorophyll index by 15.6 - 22.4 percent which was statistically similar with Lay by application of Pendimethalin (0.75kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS. Similarly, Atrazine (0.75 kg a.i ha^{-1}) as pre-emergence + Tembotrione @ 120 g ha^{-1} at 25 DAS enhanced chlorophyll index by 22.1 - 28.4 percent over weed free up to maturity and weed free by two hoeing. Due to effective control of weeds and reduced crop weed competition for resources. Similar result was observed by Mahyono *et al.* (2008) who reported that post emergence application of Toppramezone + Atrazine at 21 DAS more effectively controlled weeds and increased chlorophyll content. However, the lowest chlorophyll index was found in weedy check. Similar record was seen under the work of Thalkar and Kumar (2022).

Table 3. Effect of weed management methods on total cost, gross return, net return, and B-C ratio of spring maize during 2022.

Treatments	Total cost (ha^{-1})	Gross returns (ha^{-1})	Net returns (ha^{-1})	B-C ratio
T1	83616	95422	11806	1.14
T2	97410	148019	50610	1.52
T3	92812	142630	49818	1.54
T4	89076	129074	39998	1.45
T5	89584	128806	39222	1.44
T6	88600	118561	29960	1.34
T7	88888	119730	30843	1.35
T8	89462	126958	37496	1.42
T9	89750	127110	37360	1.42
T10	92812	129808	36996	1.4
T11	89325	121593	32268	1.36
T12	92812	130239	37427	1.4

Grain yield and biological yield

Grain yield and biological yield of spring maize was considerably (Table 2) impacted by weed management practices in 2022. Weed-free until harvest of the crop and weed-free by two hoeing at 15 and 30 DAS achieved maximum grain yield (60.83-63.17 q ha^{-1}) and biological yield (239.9-243.7 q ha^{-1}). Lay by application of Atrazine (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS enhanced grain yield by 10.9-14.2 percent and biological yield by 5.5-7.0 percent which were statistically at par with Lay by application of Pendimethalin (0.75kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS. Similarly, Atrazine (0.75 kg a.i ha^{-1}) as pre-emergence + Tembotrione @ 120 g ha^{-1} at 25 DAS enhanced grain yield by 12.4-15.7 percent and biological yield by 10.3-11.7 percent over weed free up to maturity and weed free by two hoeing. The maximum grain yield obtained in weed-free conditions was primarily the result of less crop-weed rivalry during the crop growth cycle, allowing the crop to utilize nutrients, moisture, light, and space to the fullest, favoring growth and yield components (Sivamurugan *et al*., 2017). Similarly, Lower weed density and weed dry matter accumulation in these treatments may account for the higher grain production (Swetha *et al.*, 2015). However, the lowest grain yield was found in weedy check. Similar results have also been observed by Walia *et al*. (2007) and Alok *et al*. (2012).

Economics

Economic parameters are varied with the treatments in spring maize during 2022. Maximum cost of cultivation, gross returns and net returns and B-C ratio was observed in weed free check followed by weed free by two hoeing at 15 and 20 DAS, layby application of Atrazine (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS, Lay by application of Pendimethalin (0.75 kg a.i ha^{-1}) after one hoeing at 15 to 20 DAS. Lowest economics parameters was in weedy check.

Conclusion

Various weed management methods significantly differed with respect to crop growth and development and productivity of spring maize. Weed free up to maturity of the crop showed superior but keeping the plot weed free by two hoeing at 15 and 30 DAS has recorded better performer and was statistically similar with other mechanical and cultural methods like CRIJAF weeder at 6 and 20 DAE and maize + rice crop residue mulch. Among chemical methods, lay by application of atrazine, pendimethalin and atrazine (PE) + tembotrione (PoE) were statistically at par. Single dose of POE herbicides are low performer. Hence these methods can be recommended to spring maize growers Jalandhar regions of Punjab.

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