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Influence of planting patterns and integrated weed management practices on weed biomass, growth and yield of Spring maize

Ramandeep Singh*, US Walia & Manisha Chaudhary

Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara 144 411, India

*Email: brarraman8191@gmail.com

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Abstract

Weed infestation is a serious problem in corn production that impacts global production and due to increasing food demand worldwide, certain manipulation is required in agronomic practices to improve corn production. This experiment was conducted on the Research farm of the Department of Agronomy, Lovely Professional University, Phagwara to evaluate the impact of planting patterns and integrated weed control treatments on maize crops during the *Spring* season of 2023 and 2024. The experiment was laid out in Split Plot Design with 3 planting methods in main plots viz., M1 - Flat sowing with single row, M2 - Flat sowing with paired row and M3 - Ridge sowing and 5 weed control treatments in subplots viz., T1 - atrazine + pendimethalin (0.75 + 0.75 kg/ha), pre-emergence followed by straw mulching, T2 - pendimethalin (0.60 kg ha^{-1}), pre-emergence + intercropping cowpea f. b. earthing up (EU) and straw mulching (SM), T3 - intercropping dhaincha f. b. earthing up and straw mulching, T4 - 2 hand weedings (4 and 6 WAS) and T5 - unweeded (control) with 4 replications. The results indicated that sowing of maize crops on ridges produced significantly better crop growth and yield with significantly lesser weed biomass than paired row sowing. Among the weed control treatments, the intercropping treatments, followed by earthing up and straw mulching, were effective in weed control and produced significantly higher growth and yield than other weed control treatments. It can be concluded that planting maize on ridges with intercropping followed by earthing up and straw mulching produced the best results, which can be adopted by the farmers to sustainably improve the yield and earn better profits as the methods involved are environment friendly and do not require any additional investment.

Keywords

corn yield; green manuring; ridge planting; *Spring* maize; weed control

Introduction

Maize has a wider adaptability as it can be grown in both hot and cold climates, which makes it a suitable crop for most parts of the world. Worldwide, maize is cultivated on over 193 million ha of land with 1147.7 million MT of yield. The average global productivity of maize is 5.75 tons per ha (1). India produced 38.09 MT in the year 2023. In Punjab, maize was cultivated on 93.3 thousand ha of land with 410 thousand tonnes of production and productivity of 43.93 q/ha during *Kharif* 2022-23 (2). Maize is grown for human consumption as well as fodder and feed purposes. It contains carbohydrates (71.88 g), protein (8.8 g), fat (4.57 g), fiber (2.15 g) and ash (2.33 g) per 100 g of edible portion of maize (3). Various planting patterns like flat, ridge, furrow, bed sowing, etc., have

been adopted for maize cultivation. The different methods of planting maize have an effect on its growth and development as changes in land configuration affect the available space for the crop. Yield reduction of 32.4 to 42.3 % due to weed infestation has been estimated in maize (4). The yield of the maize crop improved with ridge furrow planting along with mulching, which suppressed the weeds and allowed the crop to grow with minimum competition (5). Weeds are one of the main factors that influence crop yield to a great extent. A higher yield can be obtained with better weed management practices in maize (6). Weeds can be controlled through hand weeding, hoeing, chemical, cultural, biological and integrated methods. However, the efficiency of these methods is different and only a single method is not enough to minimize the losses due to weeds. Integrating the various methods can improve the management of weeds and yield more. The use of hand weeding along with herbicide application helped the maize crop to grow normally and produce a higher yield than the crop in which unrestricted weed growth was allowed (7). The production of straw is remarkably high and for its management, it can be used for mulching and biochar preparation (8), which is an emerging trend to reduce straw burning, which causes environmental pollution. Straw mulching is another method that helps in weed control. Straw mulching reduces evaporation and improves irrigation water use efficiency, which helps in better crop growth (9). Earthing up provides improved soil physical conditions and reduces crop lodging, which leads to a higher yield of maize (10). Improving corn production is the need of the hour as the world population is increasing rapidly and manipulating the agronomic practices of maize cultivation can be one of the methods to overcome this issue. So, this study was carried out to check the impact of various weed control methods like green manuring, mulching and herbicide spraying, along with planting methods to improve crop yield by suppressing weed competition.

Materials and Methods

The research trail was conducted at the experimental farm of the Department of Agronomy, Lovely Professional University, Phagwara, Punjab during the *Spring* season of 2023 and 2024. The Split Plot Design was used with 4 replications. Three planting methods in main plots *viz.,* M_1 - Flat sowing with single row, M_2 - Flat sowing with paired row and M_3 - Ridge sowing and 5 weed control treatments in subplots *viz.,* T_1 - atrazine + pendimethalin (0.75 + 0.75 kg/ha), pre-em. followed by straw mulching, T_2 - pendimethalin (0.60 kg ha^{-1}), pre-emergence + intercropping cowpea (*Vigna unguiculata*), followed by earthing up (EU) and straw mulching (SM), T_3 - intercropping dhaincha (*Sesbania aculeata)* followed by earthing up and straw mulching, T_4 - 2 hand weedings (4 and 6 WAS) and T_5 - unweeded (control) with 4 replications. The field was prepared by a rotavator and sowing was done using the dibbling method. The experimental field had sandy loam texture with a soil pH of 7.8 and available soil N was 212 kg ha^{-1}. The variety PMH10 was sown on 18th February 2023 and 20th February 2024. The row-to-row spacing was 60 cm in a single row and ridge sowing. However, in paired row sowing, the 2 adjacent rows 30 cm apart with spacing of 90 cm between 2 pairs were kept. The plant-to-plant spacing was kept the same *viz.,* 20 cm in each method. The plant population was uniform in all the planting methods. The gross plot size was 18 m^2. The full dose of P at 60 kg/ha was broadcasted at the time of field preparation. The nitrogen at 125 kg/ha was applied in three splits with 1/3rd dose in each split at 2, 4 and 6 WAS. In total, 12 irrigations were applied. Pre-emergence herbicides were sprayed on the same day of sowing with a knapsack sprayer equipped with a flat fan nozzle, and 350 L of water per ha was used. The intercrops were also sown with the Kera method. The intercrops were cut and laid out along the rows, followed by earthing up and straw mulching (6 t ha^{-1}) was done after 45 DAS.

For weed data, a quadrant of 30*30 cm^2 was randomly thrown in each plot twice and weed count and weed fresh weight were recorded and mean values were obtained. The weed plants were over-dried at 60 °C until a stable weight was obtained. For growth parameters, 5 plants were randomly selected from each plot and observations were recorded. The crop was harvested from the net plot of 2.4 m^2 with a sickle at 120 DAS when the leaves of the crop dried up. The plants were sun-dried for 5 days and weighed on weighing balance, then the cob sheath was removed and shelling was done with hands.

The observed data was put into Excel to calculate the mean values. Then, for the Analysis of Variance (ANOVA) of the data, OPSTAT software (HAU) was used. The level of significance was checked at 0.5 %, which is presented in the tables with SEm and C.D. values.

Results and Discussion

Weed parameters

Weed count (m^{-2}), Weed dry weight (kg / ha) and WCE (%)

The data presented in Table 1 represents the impact of different treatment combinations on weed dynamics, which was recorded at 75 DAS. The ridge planting (7.8 and 6.8) has significantly less number of weeds / sq. m. than flat sowing (7.9 and 7.3) and paired row planting (8.8 and 8.4) during 2023 and 2024 respectively. The mean % reduction in weed count was 15.11 and 11.62 % in ridge sowing and flat sowing as compared to paired row sowing based on transformed values. The weed infestation is less under ridge planting due to unfavourable conditions like the deep placement of weed seeds (11). A significantly smaller weed population was observed in both the intercropping treatments along with earthing up and straw mulching compared to other treatments. A significantly higher weed count was found in the weedy check (control) treatment (16.4 and 14.9 during 2023 and 2024 respectively). The average reduction in weed count in intercropping treatments was 93.61 % as compared to control. The use of cover crops reduces the weed infestations (12).

The dry matter accumulation was significantly less in ridge planting compared to other methods. The average % reduction in weed dry matter was 14.52 % in ridge sowing as compared to paired row planting. The lower dry weight of

Table 1. Effect of planting patterns and weed controls treatments on weed count (m^{-2}), weed dry weight (q/ha) and WCE (%) recorded at 75 DAS.

Treatments	Weed count (m^{-2})		Weed dry weight (q/ha)		Weed control efficiency (%)*	
	2023	2024	2023	2024	2023	2024
Main factor (Planting patterns)						
Flat sowing with single row	7.9 (99.5)	7.3 (84.2)	2.22 (6.41)	1.64 (2.36)	58.96	53.01
Flat sowing with paired rows	8.8 (125.2)	8.4 (111.6)	2.38 (8.09)	1.96 (4.33)	56.00	43.84
Ridge sowing	7.8 (95.5)	6.8 (71.9)	2.12 (5.67)	1.59 (2.17)	60.81	52.15
SE(m) ±	0.08	0.11	0.02	0.03		
C.D. (5 %)	0.27	0.39	0.06	0.09		
Sub factor (Weed control treatments)						
Pendi. +Atz., pre-em. *f. b.* SM	8.4 (69.5)	7.7 (59.0)	1.80 (2.24)	1.27 (0.64)	66.72	63.61
Pendi., pre-em. + inter. cowpea *f. b.* EU and SM	1.0 (0.0)	1.0 (0.0)	1.00 (0.00)	1.00 (0.00)	81.52	71.35
Inter. *Sesbania f. b.* EU and SM	1.0 (0.0)	1.0 (0.0)	1.00 (0.00)	1.00 (0.00)	81.52	71.35
Two hand weedings (4 and 6 WAS)	14.0 (196.4)	12.7 (162.8)	1.99 (2.96)	1.88 (2.57)	63.22	46.13
Unweeded (control)	16.4 (267.8)	14.9 (224.3)	5.41 (28.42)	3.49 (11.56)		
SE(m) ±	0.12	0.15	0.03	0.04		
C.D. (5 %)	0.35	0.42	0.08	0.12		
Interaction C.D. (5 %)	NS	NS	NS	NS		

Note: EU - Earthing up, SM - Straw Mulching and *f. b.* - followed by

*WCE is based on transformed data

Figures in the parenthesis are original values and figures without parentheses are transformed values.

weeds can be attributed to the lower weed populations in the ridge planting. In weed control treatments, significantly less weed dry matter was found in pendimethalin + intercropping cowpea, followed by earthing up and straw mulching and intercropping *Sesbania* followed by earthing up and straw mulching which was followed by pendimethalin + atrazine followed by straw mulching as compared to other treatments. The significantly higher weed dry matter (5.41 and 3.49) was found in unweeded (control) treatment during 2023 and 2024 respectively, based on square root transformed values. By growing cover crops, there may be a slight change in the micro-environment around the soil, which may lead to suppression of weed growth (13).

The WCE in ridge planting (60.81 and 52.15 %) was higher as compared to flat sowing (58.96 and 53.01 %) and paired row sowing (56.00 and 43.84 %) during both years respectively. As the weed count and dry weight was less under ridge plant due to which the higher weed control efficiency was found in ridge sowing as compared to other methods of planting. The weed control efficiency was highest (81.52 and 71.35 % during 2023 and 2024 respectively) in pendimethalin + intercropping cowpea, followed by earthing up and straw mulching and intercropping *Sesbania,* followed by earthing up and straw mulching followed by pendimethalin + atrazine followed by straw mulching. The WCE (63.22 and 46.13 %) was lower in 2-hand weeding (4 and 6 WAS) as compared to other treatments during both years respectively. The less dry weight was recorded under the intercropping treatments and herbicide application, which resulted in higher weed control efficiency. Similar results were reported (14, 15).

Growth attributes

Plant height (cm) and dry weight per plant (g) at 105 DAS

The data presented in Table 2 depicts the growth data at 105 DAS. The plant height (175.91 and 182.97 cm) was significantly higher in ridge plants as compared to flat and paired row sowing during both years respectively. Ridge planting produces better plant height due to improved soil conditions, which enhances the emergence and growth of maize (16). The significantly higher plant height was recorded in pendimethalin, pre-em. + intercropping cowpea followed by earthing up and straw mulching and intercropping *Sesbania* followed by earthing up and straw mulching as compared to other treatments. Pendimethalin + atrazine, pre-em. followed by earthing up and straw mulching, also produced significantly higher plant height than 2-hand weeding. Significantly lower plant height was observed in the unweeded (control) than in all other treatments. Intercropping and straw mulching reduce weed infestation and improve soil conditions, which results in better crop growth (17).

The dry matter per plant recorded at 105 DAS was significantly higher in the ridge sowing as compared to paired row sowing and it was statistically at par with flat sowing with a single row. It was observed that under ridge planting, the plant's dry weight increases more than in flat planting, which may be attributed to better emergence and reduced lodging under ridge planting (18). In subplots, the intercropping treatments produced significantly better dry weight per plant than other weed management treatments. The dry matter per plant was significantly less in the unweeded control. The average increase in dry matter per plant was 55.49 and 53.40 % in intercropping treatments as compared to control. Integrated weed management reduces weed competition and improves the growth and yield of maize crops (19).

Table 2. Effect of planting methods and weed management treatments on plant height (cm) and dry weight per plant at 105 DAS of *Spring* maize.

Treatments	Plant height (cm)		Dry weight/plant (g)	
	2023	2024	2023	2024
Main factor (Planting patterns)				
Flat sowing with single row	172.56	181.46	257.88	290.38
Flat sowing with paired rows	169.93	172.30	238.10	268.67
Ridge sowing	175.91	182.97	261.87	298.18
SE(m) ±	4.33	4.26	5.04	5.32
C.D. at 5 %	1.23	1.21	17.77	18.76
Sub factor (Weed control treatments)				
Pendi. +Atz., pre-em. *f. b.* SM	178.27	185.27	261.18	303.59
Pendi., pre-em. + inter. cowpea *f. b.* EU and SM	181.82	188.02	281.27	321.00
Inter. *Sesbania f. b.* EU and SM	180.07	187.58	272.43	321.75
Two hand weedings (4 and 6 WAS)	171.44	177.25	252.07	291.19
Unweeded (control)	152.39	156.42	196.13	191.19
SE(m) ±	3.36	3.63	7.20	3.74
C.D. at 5 %	1.17	1.26	20.72	10.77
Interaction C.D. at 5 %	NS	NS	NS	NS

Note: EU - Earthing up, SM - Straw Mulching and *f. b.* - followed by

Yield parameters

Grain yield (q / ha) and straw yield (q / ha)

The data for grain and straw yield has been presented in Table 3. The highest grain yield was obtained in the ridge sowing method (83.3 and 85.6 q /ha), followed by flat sowing (81.3 and 84.0 q / ha) during 2023 and 2024 respectively. The grain yield in paired rows was significantly less than that of other planting methods. The percent yield increase was 9.32 and 9.74 % in ridge sowing as compared to paired rows during both years. The ridge planting provides better soil conditions for root development and helps in better use of irrigation water (20, 21). The yield of maize, under the cowpea and *Sesbania* intercropping, was significantly higher than pre-em. Atrazine + pendimethalin followed by straw mulching, 2 hand weedings and weedy check (control). The yield increase was 43.51 and 45.05 % in intercropping dhaincha, followed by earthing up and straw mulching and 38.77 and 40.35 % in pendimethalin, pre-em. + intercropping cowpea followed by earthing up and straw mulching as compared to unweeded (control) during 2023 and 2024 respectively. The yield in integrated treatments *viz.,* pendimethalin, pre-em. + intercropping cowpea followed by earthing up and straw mulching and intercropping dhaincha followed by earthing up and straw mulching was more due to better control of weeds as well as the availability of good physical soil conditions. Green manuring improves the crop yield by providing a certain amount of nutrients to the crop (22). Straw mulching provides better soil water retention, which improves yield (23). The use of weed control treatments improves the grain yield of maize as crop weed competition is reduced (24).

Significantly higher straw yield was observed in the ridge sowing (60 cm) than in flat sowing (60 cm) and paired row sowing (30 cm-90 cm). The average straw yield increase was 9.3 % in ridge sowing as compared to paired row planting. The stover yield of flat sowing with a single row was significantly more than that of flat sowing with the paired row. Results support the findings of an earlier work conducted (20). Sowing on ridge provides better soil physical conditions for growth and development (25). The straw yield was significantly higher under pendimethalin + cowpea followed by earthing up and straw mulching and intercropping *Sesbania* followed by earthing up and straw mulching as compared to all the other treatments. The straw yield (190.5 and 175.3 q ha^{-1}) was significantly higher in 2-hand weeding as compared to the unweeded control

Table 3. Effect of planting methods and weed control treatments on grain yield (q/ha) and straw yield (q/ha) of *Spring* maize.

Treatments	Grain yield (q/ha)		Straw yield (q/ha)	
	2023	2024	2023	2024
Main factor (Planting patterns)				
Flat sowing with single row	81.3	84.0	195.9	183.8
Flat sowing with paired rows	76.2	78.0	188.9	169.8
Ridge sowing	83.3	85.6	198.9	193.2
SE(m) ±	1.52	1.42	2.0	3.5
C.D. at 5 %	5.36	5.02	7.0	12.3
Sub factor (Weed control treatments)				
Pendi. +Atz., pre-em. *f. b.* SM	82.3	84.7	203.0	179.1
Pendi., pre-em. + inter. cowpea *f. b.* EU and SM	87.7	89.4	215.3	203.4
Inter. dhaincha *f. b.* EU and SM	90.7	92.4	208.9	202.4
Two hand weedings (4 and 6 WAS)	77.3	82.7	190.5	175.3
Unweeded (control)	63.2	63.7	155.2	151.2
SE(m) ±	1.53	1.28	2.7	3.8
C.D. at 5 %	3.32	3.69	7.8	11.1
Interaction C.D. at 5 %	NS	NS	NS	NS

Note: EU - Earthing up, SM - Straw Mulching and *f. b.*- followed by

(155.2 and 151.2 q ha^{-1}) during both years respectively. Straw mulching reduces water evaporation, which improves water use efficiency and results in increased yield (9, 26). Legume green manuring crops accumulate nitrogen in nodules, which later, after incorporation, provide the nutrient back to the crop, which ultimately improves the straw yield (27).

Conclusion

The use of ridge planting and intercropping cowpea and dhaincha, followed by earthing up and straw mulching in combination, can be helpful in better weed control and producing higher grain yield. The farmers can use these methods for better crop production and to gain more profits as they do not require any special implementation or skill. The use of straw as mulch can reduce the amount of straw burning and upon decomposition, it will improve the physical conditions of the soil. Overall, the methods are sustainable and environment-friendly and can be used by anyone with minimal knowledge of crop production.

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Authors' contributions

RS carried out the field experiment, collection and analysis of data, participated in the sequence alignment and drafted the manuscript. USW participated in the design of the study, supervised the whole research and helped in compiling the manuscript. MC conceived the study and participated in data collection, compiling and analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None.

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