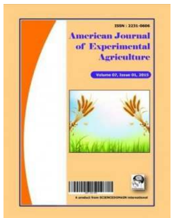

American Journal of Experimental Agriculture
14(1): 1-9, 2016, Article no.AJEA.28113
ISSN: 2231-0606

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Growth and Yield of Maize (*Zea mays* L.) as Influenced by Integrated Weed Management under Temperate Conditions of North Western Himalayas

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Authors' contributions

This work was carried out in collaboration between both authors. Author SR designed the study, wrote the protocol and wrote the first draft of the manuscript. Author MHK reviewed the experimental design and all drafts of the manuscript. Authors SR and MHK managed the analyses of the study. Authors SR and MHK performed the statistical analysis. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEA/2016/28113
Editor(s):
(1) Mirza Hasanuzzaman, Department of Agronomy, Sher-e-Bangla Agricultural University, Bangladesh.
Reviewers:
(1) W. James Grichar, Texas A & M AgriLife Research and Extension Center, USA.
(2) Ian Mashezha, Africa University, Zimbabwe.
(3) Muhammad Shehzad, The University of Poonch, Pakistan.
(4) Udensi Ekea Udensi, University of Port Harcourt, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/16324

Original Research Article

Received 2nd July 2016
Accepted 10th August 2016
Published 24th September 2016

ABSTRACT

A field experiment was conducted at Experimental Station of CSIR-IIIM, Srinagar, J&K, India during *kharif* 2013 and 2014. The experiment was laid in a randomized block design with 4 weed management practices viz., $W_{0=}$ No weeding, $W_{1=}$ Hand weeding 20 and 50 days after sowing, $W_{2=}$ atrazine @ 1.0 kg a.i ha^{-1} PRE + hand weeding 20 days after sowing and $W_{3=}$ atrazine @ 1.0 kg a.i ha^{-1} PRE + Isoproturon @ 1.0 kg a.i ha^{-1} POST. The results revealed that weed management practices W_2 at par with W_3 significantly improved plant height, number of functional leaves, leaf area index and dry matter production at different growth stages as compared to W_0, whereas W_2 took significantly more number of days for the crop to reach different phenological stages over rest of the treatments including control during both years of study. Similarly, W_2 being at par with W_3 recorded significant improvement in all yield contributing characters over W_1 and W_0. Both grain and stover yields were also significantly higher with W_2 over W_1 and W_0. Significantly higher

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biological yield and harvest index was recorded with W_3 as compared to the rest of treatments during both the years of experimentation.

Keywords: Weed management; growth; yield; yield attributes; maize.

1. INTRODUCTION

Maize (*Zea mays* L.), belonging to the grass family *Gramineae*, is believed to have originated from Mexico or Central America and spread to West Africa with early European traders in the 16^{th} century. It is the third most important cereal in the world after rice and wheat [1]. It is produced throughout the country in India under diverse environments. In industrialized countries maize is largely used as livestock feed and as a raw material for industrial products, while in developing countries, it is mainly used for human consumption. Maize is consumed mainly as second-cycle produce in the form of meat, eggs and dairy products. It is an important source of proteins (10.4%), fat (4.5%), starch (71.8%), fiber (3%), vitamins and minerals like Ca, P, S and small amounts of Na. Its flour is considered to be a good diet for heart patients due to its low gluten (protein) content [2].

Crop yield loss could be caused in high extent by increase in the weed biomass, weed density and weed species [3]. Weeds are one of the greatest limiting factors to efficient crop production. *Cynodon dactylon, Marsilea quadrifoliata, Poa annua, Echinochloa crus-galli, Ammannia auriculata, Ammannia baccifera* and *Anagallis arvensis* are common weed which are found in the study area and most of them are associated with the maize [4]. As a consequence of structural and financing problems the cultural condition of the soil deteriorates and weeds proliferate and many species are hard to kill [5].

High weed infestation result in severe reduction in crop yield as in the condition of pure corn culture, corn losses of 40– 60% have been reported [6]. Crop yield loss could be caused in high extent by increase in the weed biomass, weed density and weed species [3]. Weeds are one of the greatest limiting factors to efficient crop production. As a consequence of structural and financing problems the cultural condition of the soil deteriorates and weeds proliferate; many species are hard to kill [5]. Weed infestation, results in severe reduction in crop yield as in the condition of pure corn culture, corn losses of 40–60% have been reported [6]. During the recent years maize yields have become stagnant and this situation cannot coup to solve the food problems of ever increasing population. It is a necessity to continuously increase the production to meet the demands of people. The low productivity of the crop is due to several constraints viz., weed management practices, planting methods, nutrition etc. Weed management practices play a great role in increasing maize yields. Farmers usually give more importance to cultural practices and neglect other factors like weed control. As the maize is usually grown during the hot summer months of May and June when manual labour is difficult to employ; therefore, other methods of weed control are more feasible, less laborious, cost effective and economical.

Several weed species which are strong competitors with maize crop reduce crop yield. Weed management strategies attempt to limit the deleterious effects of weeds growing with crop plants. These effects could be quite variable, but the most common is competition for available resources. The quantities of growth factors used by weeds are thus unavailable to the crop. As there are limitations of every weed control method; therefore, integrated weed management is a good option for sustainable agriculture. It involves the combination of all the possible methods to suppress the weeds below economic threshold levels. Although some methods are effective against weeds, they prove uneconomical for the farmers or pose environmental hazards. Keeping in view the above points, the present study was undertaken to determine the effect of weed management practices on growth, yield and yield attributes of maize.

2. MATERIALS AND METHODS

2.1 Experimental Site

A field experiment was conducted at Experimental Station (33^{O} 53' 0" N and 74^{O} 55' 0" E) of CSIR of Indian Institute of Integrative Medicine, Srinagar (J&K) during *kharif* 2013 and 2014. The climate of the experimental site was mid to high altitude temperate type characterized by hot summers and severe winters. The average annual precipitation was 812 mm (average over past twenty years) and more than

80% of precipitation was received from western disturbances in the form of snow and rains. The mean maximum temperature was 16.73℃ and minimum 2.71℃ during first year (2013) and 16.73 and 2.08℃ during second year (2014), respectively. The mean maximum and minimum relative humidity was 85.74 and 86.75 and 53.75 and 58.17 per cent during 2013 and 2014, respectively. The total rainfall received during the entire growing season of 2013 and 2014 amounted to 383.70 mm and 426.10 mm, respectively.

2.2 Experimental Design and Treatment Details

The experiment was laid out in a randomized block design with 4 weed management practices viz. W_0 = no weeding, W_1 = hand weeding 20 and 50 days after sowing, W_2 = atrazine @ 1.0 kg a.i. ha^{-1} (PRE) + hand weeding 20 days after sowing and W_3 = atrazine @1.0 kg a.i. ha^{-1} (PRE) + isoproturon @ 1.0 kg a.i.ha^{-1} (POST) with 3 replications.

2.3 Land Preparation, Fertilizer Management and Inter-culture Operations

The land was irrigated after harvesting the previous crop (Oats) and then disc ploughed followed by two turns with tiller and one turn with rotavator to bring the soil to fine tilth. The block borders, plot bunds and drainage channels were made manually. The experimental plots were leveled before sowing of seed. The maize variety "C6" was sown at a spacing of 75 cm x 20 cm between rows and plants, respectively. Nitrogen, phosphorus and potassium were applied through urea, diammonium phosphate and muriate of potash, respectively. Full dose of phosphorus and potassium and 1/3rd of nitrogen were banded as per the treatment just before sowing of seed. Remaining nitrogen was top dressed in two equal splits at knee high and tasselling stages. Two herbicides viz., atrazine and isoproturon were used in this experiment. Atrazine was sprayed PRE @ 1.0 kg a.i. ha^{-1} immediately after sowing and isoproturon was sprayed as POST @ 1.0 kg a.i. ha^{-1} after the emergence of weeds.

2.4 Observations Recorded

Five randomly selected maize plants in each plot were tagged for various periodic observations. Growth parameters viz., plant height (cm), leaf area index, days to reach different phenological stages (knee high, tasseling, silking, and maturity) [7], and dry matter production (q ha^{-1}), were recorded from penultimate rows of each plot. The leaf area of each leaf was calculated by multiplying the length and maximum width. The value thus obtained was multiplied by a constant 0.73309 to get actual leaf area and then leaf area index (LAI) was calculated by dividing the leaf area per plant by ground surface provided to each plant (1200 sq. cm). Yield attributes viz., cob length, cobs $plant^{-1}$, grains cob^{-1}, cob diameter, no. of rows cob^{-1}, and 100-grain weight and number of cobs $plant^{-1}$ were recorded from five randomly selected plants from each plot. After harvesting the crop, cobs and stalks were properly sun dried and bundled. The bundle weight of each net plot was recorded and expressed as biological yield. The grain yield of each net plot was thoroughly cleaned and sun dried. The yield from each plot was recorded separately as kg $plot^{-1}$ and then converted in q ha^{-1}. After removal of the cobs from stalks in each net plot, the stalks were weighed to determine the stover yield in q ha^{-1}. Harvest index (%) was determined by dividing the weight of grains per plot at 15% moisture content by total produce per plot and multiplying by 100.

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

In addition to above yield and yield attributed of maize, weed density and weed dry matter (q ha^{-1}) at different growth stages were also recorded during the study. 1m^2 quadrant was randomly thrown in each plot at knee high, tasselling, silking and maturity stages. Weeds under the quadrant were carefully cut at ground level and total number of weeds m^{-2} were counted and the weed samples collected from 1 m^2 quadrant in each plot were counted species wise at different growth stages. These samples were oven dried at 60℃ temperature to a constant weight and total dry matter accumulation of weeds m^{-2} was recorded and expressed in q ha^{-1}.

2.5 Statistical Analysis

The data obtained in respect of various observations were statistically analyzed by the method described by [8]. The significance of "F" and "t" was tested at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Growth Characters

A perusal of the data (Tables 1a, b) indicates that weed management practices W_2 (atrazine @ 1.0

kg a.i ha^{-1} PRE + hand weeding 20 DAS) while remaining at par with W_3 (atrazine 1.0 kg a.i ha^{-1} PRE + isoproturon @ 1.0 kg a.i ha^{-1} POST) recorded the taller plants as compared to W_1 (hand weeding 20 and 50 days after sowing) and W0 (no weeding). This is true at all the stages of growth i.e. knee height, tasseling, silking and maturity during both the years of experimentation. The height of plant is an important growth character directly linked with the productive potential of plant in terms of fodder grains and yield. Plant height has been reported to be positively correlated with productivity of plants [9]. This may be attributed to higher weed densities under the treatment that had compete with maize for nutrients, soil moisture, height and carbon dioxide [8]. Among herbicide treatments W_2 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + hand weeding 20 DAS) at par with W_3 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + isoproturon @ 1.0 kg a.i. ha^{-1} POST) produced significantly taller plants than other treatments. This was probably due to better weed control with the treatments that enabled lower densities of weeds to compete with crop for resources. Similar results were also reported by [10,11]. Results from the study showed that W_2 (atrazine @ 1.0 kg a.i ha^{-1} PRE + hand weeding 20 DAS) and W_3 (atrazine 1.0 kg a.i ha^{-1} PRE + isoproturon @ 1.0 kg a.i ha^{-1} POST) registered significantly higher number of functional leaves at all stages of growth during both the years of experimentation compared to W_1 (hand weeding 20 and 50 days after sowing) and W_0 (no weeding). This might be attributed to severe competition of high weed densities for resources viz; sunlight, moisture and nutrients thereby making maize plants weaker enough to produce more functional leaves which was closely followed by W_3 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + isoprutron @ 1.0 kg a.i. ha^{-1} POST). The reasons for this might be that atrazine functions by binding to the plasto quinine-binding protein in photosynthesis II. Weed death results from starvation and oxidative damage caused by breakdown in the electron transport process. The oxidative damage is accelerated at high light intensity [12].

Significantly higher leaf area was recorded with treatment W_3 (atrazine @1.0 kg a.i ha^{-1} PRE + isoproturon @ 1.0 kg a.i. ha^{-1} POST), however, it remained at par with W_2 (atrazine @1.0 kg ha^{-1} PRE + hand weeding 20 DAS), while significantly lower leaf area index was observed in no weeding treatment at all crop growth stages. This might be due to severe competition of weeds for growth resources which made the crop plant in efficient to utilize the higher leaf area index at various growth stages was noticed under W_2 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + hand weeding 20 DAS) and W_3 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + isoprutron @ 1.0 kg a.i. ha^{-1} POST) treatments (Tables 1a, b). This could be attributed to better control of weeds in early growth stages of crop which provided the crop plants optimum environment to utilize growth resources efficiently resulting in better growth of crop. The herbicide treatment W_2 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + hand weeding 20 DAS) took more number of days for crop to reach various phenological stages. This could be attributed to the fact that reduced competition with weeds for nutrients especially higher supply of nitrogen might have enhanced the vegetative phase of crop and delaying its maturity.

The study revealed that dry matter production at different crop growth stages increased significantly upto W_2 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + hand weeding 20 DAS) treatment (Tables 1a, b). In fact, plant dry matter accumulation depends on the quantity of total carbon fixed by photosynthesis and the fraction of that carbon converted to dry matter [13]. In addition to the presence of biotic and a biotic stresses, plant dry matter accumulation depends on the quantity of radiation absorbed by the canopy [14]. The higher dry matter recorded under W_2 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + hand weeding 20 DAS) treatment could be possibly due to better weed control and weed control efficiency resulting in lower weed density and higher dry matter. In addition, lower weed competition with maize, taller maize plants, higher LAI, higher efficiency in intercepting and absorbing solar radiation and partitioning of assimilate and inorganic nutrients may have promoted higher dry matter accumulation under W_2 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + hand weeding 20 DAS) treatment. The results are in line with those reported by [9,11,15].

3.2 Yield and Yield Attributing Characters

Various yield contributing characters viz., cob length and diameter cobs per plant grain rows and number of grains per plant and 100-seed weight recorded under W_2 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + hand weeding 20 DAS) and W_3 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + isoproturon @ 1.0 kg a.i. ha^{-1} POST) treatment as well as unweeded treatments were significantly higher than other weed control treatment as well as unweeded treatment (Table 2). In fact reduced

Table 1a. Growth characters of maize as affected by integrated weed management

Treatments	Growth stages							
	2013				2014			
	Knee high	Tasseling	Silking	Maturity	Knee high	Tasseling	Silking	Maturity
Plant height (cm)								
W_0	50.22	155.15	160.97	163.87	51.21	153.09	160.38	164.38
W_1	54.19	161.13	168.56	172.72	55.43	163.01	169.46	174.43
W_2	59.31	167.52	175.64	181.42	59.84	169.07	177.51	182.14
W_3	58.28	166.63	173.99	179.63	58.49	167.18	175.81	180.37
SE(m)±	0.791	0.953	1.183	1.187	0.796	1.054	1.193	1.230
CD (p=0.05)	2.435	2.934	3.645	3.657	2.451	3.247	3.675	3.789
Number of functional leaves								
W_0	3.58	8.78	8.29	3.53	4.88	9.98	8.99	3.74
W_1	5.44	10.24	9.89	4.09	5.97	10.58	9.82	4.05
W_2	7.18	11.28	11.40	4.31	8.11	11.03	12.03	4.57
W_3	6.95	11.13	11.06	4.29	7.31	10.90	10.26	4.38
SE(m)±	0.108	0.192	0.125	0.090	0.312	0.271	0.334	0.177
CD (p=0.05)	0.334	0.590	0.384	0.277	0.960	0.836	1.030	0.545
Leaf area index								
W_0	1.24	2.08	1.63	1.35	1.23	1.92	1.49	1.20
W_1	1.73	2.64	2.44	1.83	1.79	2.74	2.49	1.85
W_2	1.85	2.80	2.68	1.93	1.88	2.93	2.79	2.02
W_3	1.87	2.82	2.70	2.06	1.89	2.95	2.84	2.06
SE(m) ±	0.032	0.017	0.029	0.034	0.020	0.028	0.033	0.033
CD (p=0.05)	0.098	0.051	0.089	0.105	0.062	0.085	0.102	0.101

Where, W_0 = No weeding, W_1= Hand weeding 20 and 50 DAS, W_2 = Atrazine @ 1.0 kg a.i ha^{-1} pre emergence + Hand weeding 20 DAS and W_3 = Atrazine @1.0 kg a.i. ha^{-1} pre emergence + Isoproturon @ 1.0 Kg a.i. post emergence)

Table 1b. Growth characters of maize as affected by integrated weed management

Treatments	Growth stages							
	2013				2014			
	Knee high	Tasseling	Silking	Maturity	Knee high	Tasseling	Silking	Maturity
Dry matter production (q ha^{-1})								
W_0	6.28	38.27	61.32	92.83	6.31	39.59	63.28	95.50
W_1	6.91	43.27	68.74	102.95	6.99	43.47	69.03	105.35
W_2	7.38	47.03	74.31	110.55	7.93	50.18	78.96	114.91
W_3	7.30	46.40	73.37	109.27	7.67	48.11	75.90	112.73
SE(m) ±	0.061	0.934	1.180	1.549	0.211	0.920	1.231	1.583
CD (p=0.05)	0.189	2.876	3.635	4.772	0.651	2.833	3.792	4.875
Days taken to phenological stages								
W_0	37.73	70.90	96.78	122.08	37.72	71.83	97.35	121.53
W_1	39.13	72.52	98.03	123.18	38.95	71.90	99.03	122.17
W_2	41.78	75.30	100.82	126.75	41.30	74.30	101.12	125.25
W_3	39.95	73.37	98.87	124.82	39.73	72.27	99.80	124.48
SE(m) ±	0.466	0.441	0.505	0.473	0.466	0.478	0.769	0.898
CD (p=0.05)	1.435	1.356	1.554	1.456	1.434	1.473	2.363	2.756

Where, W_0 = No weeding, W_1= Hand weeding 20 and 50 DAS, W_2 = Atrazine @ 1.0 kg a.i ha^{-1} pre emergence + Hand weeding 20 DAS and W_3 = Atrazine @1.0 kg a.i. ha^{-1} pre emergence + Isoproturon @ 1.0 Kg a.i. post emergence)

weed competition due to atrazine applied PRE allowed the crop stand growth better and utilize the available nutrients especially nitrogen which is because of its cell division and cell elongation role improved cob length and diameter as well as number of cobs per plant. Higher number of grains per cob could be attributed to better translocation of metabolites for seed development and decrease in number of grains in W_1 (hand weeding 20 and 50 days after sowing) and W_0 (no weeding) treatments was due to increase in weed competition [16,17,18] reported that maximum 100-seed weight was recorded with pre-emergence application of atrazine at 0.50 kg a.i ha^{-1} in combination with pendimethalin at 0.25 kg a.i ha^{-1}.

The results of the investigation reveal that the lowest grain yield was found under unweeded treatments (Table 3). This could be attributed to greater renewal of nutrients and moisture by weeds and a severe crop weed competition resulted in poor source and sink development with poor yield components. These results are similar to other reported research [11,19,20]. Among weed control treatments W_2 (atrazine @1.0 kg a.i. ha^{-1} PRE + hand weeding 20 DAS) followed by W_3 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + isoproturon @ 1.0 kg a.i. ha^{-1} POST) recorded maximum grain yield which could be attributed to improved yield component viz.; higher number of cobs/plant, grains per cob and 100-grain weight. This improvement in turn was due to higher dry matter production and distribution in different parts, higher LA1 [21]. This implies that with effective and efficient weed control, more plant nutrients are made available to the crop for enhanced leaf area formation that increases solar radiation interception thereby favouring better utilization of photosynthesis for higher grain yield. Both stover and biological yield were also significantly higher under W_2 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + hand weeding 20 DAS) and W_3 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + isoproturon @ 1.0 kg a.i. ha^{-1} POST) treatments (Table 3). Higher biological yield and stover yield is the effect of higher plant height, more number of functional leaves and higher dry matter production. Harvest index is defined as a ratio of yield biomass to the total biomass at harvest [17,22,23]. During the study it was found that lowest harvest index was observed under no weeding W_0 (no weeding) treatment which could be attributed to higher partitioning of assimilates to vegetative biomass at the expense of sink (grains). Significantly higher harvest index was observed under W_2 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + hand weeding 20 DAS) treatment though at par with W_3 (atrazine @ 1.0 kg a.i. ha^{-1} PRE + isoproturon @ 1.0 kg a.i. ha^{-1} POST). This could be attributed to adequate suppression of weed growth as well as more availability of plant nutrients to maize crop which favoured better utilization of photo-assimilates for grain yield formation. Similar results have been discussed by [9,24].

Table 2. Yield contributing characters of maize as affected by integrated weed management

Treatments	Cob length (cm)	Cobs $plant^{-1}$	Grains cob^{-1}	Cob diameter (cm)	Number of rows cob^{-1}	100-grain weight (g)
2013						
W_0	11.83	1.065	390.00	1.58	12.83	18.70
W_1	12.91	1.100	409.22	1.93	15.94	20.02
W_2	14.11	1.123	425.67	2.23	18.63	22.27
W_3	14.06	1.11	421.83	2.21	16.19	21.26
SE(m) $\pm$	0.065	0.017	2.331	0.091	0.26	0.299
CD (p=0.05)	0.20	NS	7.18	0.28	0.78	0.92
2014	13.96	1.12	416.18	2.09	16.31	20.66
W_0	14.05	1.09	399.06	1.78	13.92	18.59
W_1	15.09	1.11	419.95	2.06	16.11	20.29
W_2	16.45	1.13	433.11	2.31	17.92	22.38
W_3	16.21	1.13	429.50	2.20	16.80	22.07
SE(m) $\pm$	0.305	0.009	2.575	0.049	0.24	0.328
CD (p=0.05)	0.94	0.03	7.93	0.15	0.69	1.01

Where, W_0 = No weeding, W_1= Hand weeding 20 and 50 DAS, W_2 = Atrazine @ 1.0 kg a.i ha^{-1} pre emergence + Hand weeding 20 DAS and W_3 = Atrazine @1.0 kg a.i. ha^{-1} pre emergence + Isoproturon @ 1.0 Kg a.i. post emergence)

Table 3. Yield and harvest index of maize as affected by integrated weed management

Treatments	2013				2014			
	Biological yield	Harvest index	Seed yield	Stover yield	Biological yield	Harvest index	Seed yield	Stover yield
W_0	101.88	39.31	40.83	63.05	103.58	40.03	42.27	63.31
W_1	110.40	39.59	44.89	68.51	112.12	40.24	46.32	68.80
W_2	122.69	40.71	49.54	72.14	124.25	41.13	50.69	72.56
W_3	119.40	40.66	48.96	71.45	120.82	41.03	49.99	71.83
SE(m) $\pm$	2.064	0.045	0.240	0.759	2.337	0.052	0.266	0.652
CD (p=0.05)	6.36	0.14	0.74	1.94	7.20	0.16	0.82	1.21

Where, W_0 = No weeding, W_1= Hand weeding 20 and 50 DAS, W_2 = Atrazine @ 1.0 kg a.i ha^{-1} pre emergence + Hand weeding 20 DAS and W_3 = Atrazine @1.0 kg a.i. ha^{-1} pre emergence + Isoproturon @ 1.0 Kg a.i. post emergence)

Table 4. Weed density and dry matter as affected by integrated weed management

Treatments	Growth stages							
	2013				2014			
	Knee high	Tasseling	Silking	Maturity	Knee high	Tasseling	Silking	Maturity
Weed density (g m^{-2})								
W_0	3.17	4.31	4.66	4.92	3.17	3.72	4.34	4.86
W_1	2.84	3.40	3.67	3.73	2.63	3.06	3.69	3.69
W_2	2.04	2.47	2.59	2.65	1.83	2.26	2.61	2.84
W_3	2.31	2.99	3.29	3.38	2.10	2.74	3.04	3.17
SE(m) $\pm$	0.048	0.048	0.071	0.067	0.052	0.042	0.056	0.052
CD (p=0.05)	0.15	0.15	0.18	0.21	0.16	0.13	0.17	0.16
Weed dry matter production (q ha^{-1})								
W_0	16.93	21.50	25.70	27.87	16.98	22.96	25.62	28.31
W_1	13.40	17.38	21.94	22.52	13.73	17.47	19.88	23.35
W_2	10.23	11.25	15.92	16.82	10.26	11.96	13.85	15.49
W_3	11.56	12.90	16.99	19.12	10.51	12.66	14.94	17.07
SE(m) $\pm$	0.110	0.233	0.318	0.307	0.119	0.192	0.254	0.294
CD (p=0.05)	0.340	0.718	0.978	0.947	0.367	0.592	0.782	0.904

Where, W_0 = No weeding, W_1= Hand weeding 20 and 50 DAS, W_2 = Atrazine @ 1.0 kg a.i ha^{-1} pre emergence + Hand weeding 20 DAS and W_3 = Atrazine @1.0 kg a.i. ha^{-1} pre emergence + Isoproturon @ 1.0 Kg a.i. post emergence)

3.3 Weed Studies

A perusal of data (Table 4) indicates that W_3 (atrazine @ 1.0 *a.i* kg ha^{-1} + hand weeding 20 DAS) recorded significantly higher weed density over W_2 (atrazine @ 1.0 *a.i* kg ha^{-1} PRE +isoproturon @ 1.0 *a.i* kg ha^{-1} POST). Similarly, the same treatment W_3 (atrazine @ 1.0 *a.i* kg ha^{-1} + isoproturon @ 1.0 *a.i* kg ha^{-1} POST) noticed the increased weed dry matter over W_2 (atrazine @ 1.0 *a.i* kg ha^{-1} + hand weeding 20 DAS). Significantly maximum weed density and weed dry matter were observed under W_0 (no weeding) treatment during both years of investigation. Higher weed density at W_3 might mean that there was a high weed seed population in the soil with high germination capacity that responded positively to favourable environmental factors and many weed seedlings were able to survive. According to Hamayun [2], at this stage in the growth of the seedling weeds and crops, much negative interaction might have not set in. However, as weed and crop seedlings grew older and developed more structures such as roots and root hairs as well as photosynthetic apparatus necessary for tapping the growth factors in the plants environment, competition among seedlings for the growth factors as well as allelopathy was intensified. Weeds that were more aggressive, persistent and resistant to control might have outgrown, smothered and killed the weaker ones, and thereby progressively reduced weed population during the growth period. The high dry matter of control treatment (W_0) as compared to all other treatments might be probably due to the fact that weed treatments provided better weed control and had lower weed densities. These findings are in agreement with [25], who attributed reduced weed dry matter in maize to the effectiveness of primextra (a pre-emergence herbicide) in weed control with its corresponding lowered weed density. Yadav [26] and Chikoye [27] also reported that the usage of pre-emergence herbicide proved best treatment, reducing the dry weight of weeds by 80 to 88%.

4. CONCLUSION

Various aspects of the present investigation and observation generated showed that all growth, yield and yield attributing traits were discernible influenced various weed management practices. Results clearly suggested that for temperate environment of Kashmir Valley, from stand point of higher growth and yield of maize, the application of atrazine @ 1.0 kg a.i ha^{-1} PRE + hand weeding 20 days after sowing or atrazine @ 1.0 kg a.i ha^{-1} PRE + Isoproturon @ 1.0 kg a.i ha^{-1} POST were found to be appropriate weed management practices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/ 16324