Agronomy Journal of Nepal. ***6****(1):145-152*
ISSN: 2091-0649 (Print)
DOI: https://doi.org/10.3126/ajn.v6i1.47957

Integrated Weed Management in Summer Maize in Mid-hills of Nepal

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Received: May 15, 2022
Revised: June 25, 2022
Published: July 08, 2022

ABSTRACT

Weed is one of the major problems in maize production. To develop an appropriate weed management practice, a field experiment was carried out during 2017 and 2018 at Khumaltar. Twelve different treatments, Pendimethalin as pre @ 1.0 kg a.i ha^{-1}, Atrazine as pre @ 1 kg a.i ha^{-1}, Metribuzine as pre @ 0.5 kg a.i ha^{-1}, Tembotrione as post @ 0.2 kg a.i ha^{-1}, Pendimethalin followed by (fb) 1 HW, Atrazine fb 1 HW, Metribuzine fb 1 HW, Tembotrione fb 1 HW, Atrazine + Metribuzine (early post) as tank mixed, Straw mulch, Weed free (2 HW) and Weedy check (control) were evaluated in Randomized Complete Block Design (RCBD) with three replications. The experimental plot size was 12 m^2 and maize variety Manakamana -4 was sown on 21 and 26 May in 2017 and 2018 respectively. The seed rate used was 20 kg ha^{-1} with row spacing of 60 cm and plant to plant 20 cm. Fertilizers dose of 120:60:40 kg $N:P_2O_5:K_2O$ kg ha^{-1} was applied. Data on crop growth, weed and yields were recorded and analyzed. Weed count and biomass were recorded from a meter square quadrat and yield data taken from net plot of 5.4 m^2. Results showed that plant height with straw mulch was maximum of 294 cm. Weed density was significantly influenced by different weed management treatments. Metribuzine post fb 1 HW recorded the less weeds (52.8) and highest (258.5) in weedy check. The lowest weed dry biomass was recorded in Metribuzine post fb 1 HW (9.3 g m^{-2}). The highest grain yield (7.6 Mt ha^{-1}) was found in Metribuzine @ 0.5 kg a.i ha^{-1} as post emergence. The increased in grain yield due to the application of Metribuzine @ 0.5 kg a.i ha^{-1} as post emergence was 32.5% over the weedy check. Similarly, the highest weed control efficiency (77.1%) and the highest BC ratio (2.46) was also recorded in Metribuzine @ 0.5 kg a.i ha^{-1} as post emergence.

Keywords: Integrated, maize Metribuzine, weed, yield

How to cite this article:
Bhattarai RK, B Chaulagain, P Gyawaly, TB Karki, R Neupane, SK Das, S Kaduwal. 2022. Integrated weed management in summer maize in mid-hills of Nepal. Agronomy Journal of Nepal. **6**(1):145-152. DOI: https://doi.org/10.3126/ajn.v6i1.47957

INTRODUCTION

Maize (Zea mays L.), is one of the most important cereal crops grown in 193.7 million ha and production of 1147.7 million Mt. (FAOSTAT 2020) in the world and in Nepal, it is grown in the area of 0.976 million ha with production of 29.9 million Mt. (MOAD 2020/21). Among the cereals crops it has the highest yield potential and referred as 'queen of cereals'. Weed is a major problem in maize and competes for nutrient, water and sunlight. The reduction in maize yield due to uncontrolled weed growth reached around 32.4-50% (Sharma et al 2000) and up to 90% (Dalley et al 2006).The most dominant method is manual weeding to control weeds in Nepal, but its different from hills to Terai and farmers don't practice any single methods to control weed. Karki et al (2010) reported 48% grain yield losses due to weeds in the hills of Nepal. Timely weed management will increase the maize grain yield and also improve the quality.

The global trend of manual labour getting scarce and costly, the use of herbicides will prove cheap, timely and easy methods of managing weeds in maize crop. Herbicidal weed control allows maize plants for early growth without competition with weeds and increase in production. However, the efficacy of herbicides in maize depends on selection of right herbicides molecules, its critical time of application, and the correct weather forecast and soil moisture. Commonly atrazine is used worldwide in maize and is also applied in Nepal. However, the probability of developing resistance to weeds is high due to wide spread use of single herbicide. Mulching by straw can reduce evaporation from soil and soil erosion, water in the soil is increase, help to regulate soil temperature, increase soil enzyme activity in the soil is enhances ,and weeds growth is reduce (Akhtar et al 2018; Yang et al 2020). A straw of 6000 kg ha^{-1} and N application rate of 100 kg ha^{-1} had shown the great positive effect on maize yield (Quin et al 2021). Good agronomic practices such as depth and timeliness of tillage operation with retaining crop residues on soil surface can effectively improve weed control efficiency in maize (Chauhan et al 2012). Use of pre-emergence herbicide like Pendimethalin proved effective for controlling grassy weeds in no tillage system. (Blaise et al 2015). In conventional tillage pre-emergence herbicide Pendimethalin at 1.0 kg ha^{-1} followed by hand weeding at 40 DAS recorded lower weed density and weed biomass (Baskaran and Kavimani 2014). Therefore, it is necessary to use new herbicides molecules, their combinations and mulches, to widen the spectrum of weed management and to reduce the risk of developing weed species resistance to herbicides (Tagour and Mosaad 2017). Keeping these facts in view a field experiment was designed to identify appropriate herbicide for weed management in summer maize.

MATERIALS AND METHODS

The field experiment was conducted during 2017 and 2018 in the Agronomy Research field at Khumaltar in summer maize. Four herbicides, a straw mulch, and hand weeding were integrated making twelve treatments. The treatments were 1) Pendimethalin as pre @ 1.0 kg a.i ha^{-1} 2) Atrazine as pre @ 1 kg a.i ha^{-1} 3) Metribuzine as pre @ 0.5 kg a.i ha^{-1} 4) Tembotrione as post @ 0.2 kg a.i ha^{-1} 5) Pendimethalin as pre Fb 1HW 6) Atrazine as pre Fb 1 HW 7) Metribuzine as post Fb 1 HW 8) Tembotrione as post Fb 1 HW 9) Atrazine + Metribuzine (early post) as tank mixed 10) Straw mulch 11)Weed free (2 HW) and 12)Weedy check. The treatments were replicated three times in Randomized Complete Block Design. The experimental plot size was 12 m^2 with row spacing of 60 cm and plant to plant 20 cm. The seed rate 20 kg ha^{-1} of maize variety Manakamana 4 was sown in 21 and 26 May in 2017 and 2018 respectively. Fertilizers dose of 120: 60: 40 kg N:P_2O_5:K_2O kg ha^{-1} was applied. Herbicides were sprayed using flat fan nozzle in a knap sack sprayer. The herbicides Pendimethalin, Atrazine and Metribuzine as pre

emergence were applied on the same day after sowing of maize crop. In the mulch treatment, a thin layer of dry rice straw@ 2 Mt ha^{-1} was used as mulch. Crop growth, weed population, weed biomass and yield data were taken and analyzed. Plant height were taken from 10 plants per plot, weeds count and biomass were recorded from an area of one meter square quadrat. Number of cobs per plant was taken from 10 random plants and grain and straw yield were taken from 3 rows (5.4 m^2) at crop maturity and converted into hectare.

Table 1.Treatments detail

SN	Treatments	Dose in a.i kg ha^{-1}	Application time	Treatment Notation
1	Pendimethalin	1.0	Pre emergence(Pre)	Pendi
2	Atrazine	1.0	Pre emergence(Pre)	Atra
3	Metribuzine	0.5	Pre emergence (pre)	Metri
4	Tembotrione	0.2	Post emergence (post)	Tembo
5	Pendimethaline Fb 1 HW	1.0	Pre emergence(Pre)	Pendi fb HW
6	Atrazine Fb 1 HW	1.0	Pre emergence(Pre	Atra fb HW
7	Metribuzine Fb 1HW	0.5	Post emergence (post)	Metri fb HW
8	Tembotrione Fb1 HW	0.2	Post emergence (post)	Tembo fb HW
9	Atrazine+ Metribuzine (early post) as tank mixed	1.0 + 0.5	Post emergence (post)	Atra + Metri
10	Mulch (straw mulch)	2.0 t		Mulch
11	weed free (2 HW)	1.0	Pre emergence(Pre)	Weed free
12	Weedy check	1.0	Pre emergence(Pre)	Control

$$\text{WCE \%} = \frac{\text{Weed count in the control plot – weed count in treated plot}}{\text{Weed count in control plot}} \times 100$$

For the economics analysis, total costs (variable and fixed costs) were calculated based on the current market prices of all the inputs. Total return was derived by multiplying the yield by the existing market price (Rs 30). Benefits calculated by deducting of the total cost incurred from total returns. And benefit-cost ratio obtained by dividing the benefits by the total cost of the individual treatments. Data were analyzed using Excel 2013 and software STAR (Statistical Tool for Agricultural Research).

Soil characteristics

The soil texture of the experimental site was silty clay loam (Sand 17.3%, Silt 57.1%, and Clay 25.6%). The soil was acidic (5.98 pH), low in organic matter (2.01%), medium in total nitrogen (0.14%) and high P_2O_5 (478.8 kg ha^{-1}) and medium K_2O (160.5 kg ha^{-1}).

Weather conditions

The maximum and minimum temperature during the crop periods (May to September, 2017) was recorded ranging from 27.6 to 29.3 $^{\circ}$C and 16.3 to 20.6 $^{\circ}$C respectively and total rainfall received was 902.2 mm. During the second crop (May to September, 2018) the maximum and minimum temperature ranged from 26.9 - 29.1°C and 16.5 -20.8 $^{\circ}$C respectively and the total rainfall was 950.7 mm.The rainfall was more during 2017 at the time of sowing (May) and harvesting (September) and the yield was less than during the year 2018.

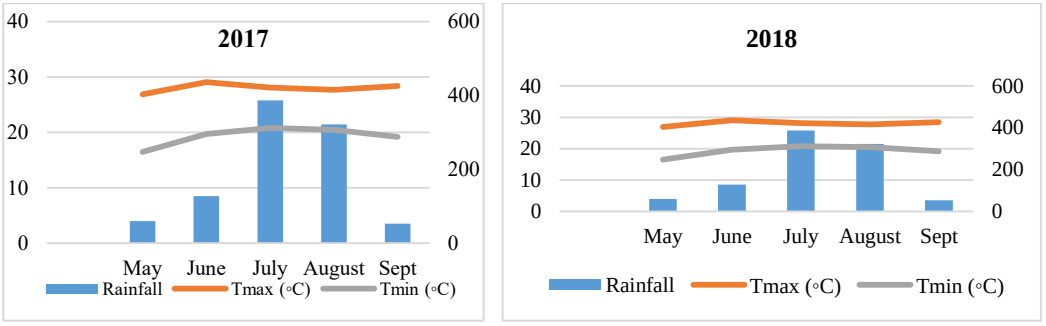

Figure 1. Monthly total rainfall (mm), mean minimum and maximum temperatures (^{o}C) at Khumaltar during 2017 and 2018 (May–September)

RESULTS AND DISCUSSION

Plant height

The different treatment showed significant difference in plant height. The plant height ranged from 270-294 cm (Table 2). The maximum plant height (294 cm) was recorded in the treatment with straw mulch and the minimum was in treatment with Pendimethaline as pre @ 1.0 kg a.i ha^{-1}. The straw mulch used showed vigorous plant growth due to reduced moisture through evaporation and the temperature build up and thus a different micro climate developed compared to others treatment plots. Lan et al (2020) also found that straw mulch influenced growth and temperature of maize crop.

Table 2. Effect of weed management options on plant growth, weeds control and yield in maize (pooled data of two years, 2017 and 2018)

Treatments	Pht (cm)	Cob length (cm)	200 GWT (g)	Grain yield kg ha^{-1}	B. Yield kg ha^{-1}	Weed m^{-2}	Trn weed m^{-2}
Pendi	270	16.7	63.75	7628	17752	214.6	14.5
Atra	275	17.2	67.53	7408	17647	105.1	9.9
Metri	273	18.8	69.32	7655	18938	59.1	7.5
Tembo	270	16.8	64.07	7301	16457	109.8	10.4
Pendi fb HW	288	17.0	67.20	6201	17702	101	9.2
Atra fb HW	278	17.3	67.29	6758	21707	81.5	7.7
Metri fb HW	280	17.8	68.58	7263	20508	52.8	6.7
Tembo fb HW	272	17.3	66.45	6266	18329	156.3	11.7
Atra + Metri	282	18.2	65.46	7341	16659	72.6	8.3 c
Mulch	294	17.3	65.24	6236	17252	153.3	12.1
Weed free	288	17.0	63.98	5954	17859	94.6	9.7
Control	284	14.8	63.38	5776	15558	258.5	15.8
Mean	**280**	**17.2**	**66**	**6816**	**18031**	**122**	**10.5**
LSD (<0.05)	11.4	ns	2.3	928	2549	132	6.2
CV (%)	5.6	11.5	3.5	12	14.2	55	30

Note: Pht. = plant height, 200 GWT=200 grain weight, B.yield =biological yield, Trn weed =transformed weed

Weed dynamics

The dominant weed in the experimental plots were *Commelina* sp., *Gallinsoga parviflora*, *Digitaria* spp, *Echinochloa colona*, *Ageratum conyzoides*, *Physalis* sp., *Alternanthera* sp., and *Bindens* sp. The weeds populations differed among the different treatments. The numbers of weed per meter square ranged from 52 to 258.The lowest weeds number were recorded in Metribuzine applied as pre emergence fb 1HW showing the highest efficacy of the treatment. Metribuzin application showed good control of all type of weeds. The two –hand weeding treatments plots also showed less number of weeds compared to the unweeded control plots. Similar, finding with reduced weeds number in metribuzin was reported by Tagour and Mosaad (2017) and in two hand weeding was reported by Shrestha et al (2021). In contrast, the highest weed numbers (258) was found in the control plot. Number of broadleaf ranged from 1.5 to 169.4 per meter square, with lowest broadleaf in Metribuzine fb 1HW treatment and the highest in the control. The mean difference was significant. The reduction in the number of broadleaf due to application of metribuzin was also reported by Shaba et al (2015) The grassy weed number ranged from 2.9 to 32.3 m^{-2} with lowest grassy weed in the treatment Pendimethalin as pre fb 1 HW and the highest is in the control. The variation in the weed numbers was found significant. The less grassy weed in maize due to the use of Pendimethalin was also observed by Shaba et al (2015).

Weed dry biomass

Weed dry biomass differed among the different treatment significantly. The biomass ranged from 9.3 to 180.1 gram per meter square. The lowest weed dry biomass recorded in Metribuzine applied as pre emergence fb 1HW**,** while the highest biomass was found in the control treatment. Atrazine fb 1HW also recorded comparatively less dry weight than other treatments. There was luxuriant growth of weeds in the no weeding treatment (control) and others less efficient treatment which resulted in more weed dry biomass. The variation in the weed dry biomass might be due to the difference in the mode of action of the various herbicides applied and their inhibition effect on growth and development. Similar, finding was also reported by Shaba et al (2015).

Yield attributes and yield

The length of the cob ranged from 14.8 to 18.8 cm with lowest and highest cob length of maize plant found in the treatment weedy check control and Metribuzine applied as pre fb 1HW respectively. However, there was no significant difference in the cob length. The longest cob length recorded in the Metribuzine applied treatment might be due to less weed growth and consequently less competition imposed to maize crop helped plant grow stress freely.

200 seed weight among the different treatment ranged from 63.38 to 69.32 gram with lowest and highest seed rate measured in the control and Metribuzine applied as pre emergence treatment respectively. The treatments mean difference were significantly difference. The higher grain weight in the Metribuzin sprayed plots might be due to enhanced flow of photosynthates from source to sink and contrast in case of control for less grain size. Muhammad et al (2022) also reported similar results of increased grain size in wheat.

Table 3. Effect of weed management options on plant growth, weeds control and yield in maize (pooled data of two years, 2017 and 2018)

Treatments	Bl weed m^{-2}	G weed m^{-2}	Weed DWT m^{-2}	WCE %	Total cost (NRs)	Total Benefit (NRs)	BCR
Pendi	66.3	9.4	84.2	17.0	69800	167590	2.40
Atra	27.4	31.1	59.8	59.3	68100	153480	2.25
Metri	17.6	13.1	31.1	77.1	68740	169520	2.46
Tembo	41.1	5.9	47.1	57.5	74965	148535	1.98
Pendi fb HW	24.8	2.9	28.0	60.9	79800	103020	1.29
Atra fb HW	5.4	7.7	13.2	68.5	78100	130400	1.66
Metri fb HW	1.5	7.8	9.3	79.6	78740	150160	1.90
Tembo fb HW	27.4	17.1	44.3	39.5	85145	115705	1.35
Atra + Metri	6.5	34.0	40.6	71.9	70340	156940	2.23
Mulch	22.3	14.3	53.4	40.7	72500	125980	1.73
Weed free	22.1	16.7	39.2	63.4	86500	92090	1.06
Control	169.4	32.3	180.1	0	66500	114820	1.72
LSD (<0.05)	124	20.2	135	-	-	-	-
CV (%)	40	39	56	-	-	-	-

Note:BL=Broadleaf weed, G=Grassy weed, DWT =Dry weight, WCE=weed control efficiency, BCR=Benefit cost ratio

Biological and grain yield

The biological yield of the different compared treatments ranged from 15558 to 21707 kg ha^{-1} with lowest in the control and highest in the atrazine fb 1 HW treatment. There was significant difference among the treatment in the biological yield.

There was significant difference in the yield. The grain yield of the different treatment ranged from 5776 to 7655 kg ha^{-1} with lowest yield observed in control and highest in the Metribuzin applied as pre emergence fb 1 HW treatment. The subsequently higher yield (7628 kg ha^{-1}) was recorded in Pendimethalin applied as pre emergence.

Weed control efficiency percentage (WCE)

The different treatment showed level of weed control. The efficiency of weed control in percentage ranged from 17 to 77. The highest WCE was found in metribuzin applied as pre emergence @ 0.5 kg a.i ha^{-1} (77.1%) while the lowest was found in the Pendimethalin applied as pre emergence treatment (17%).

Economics

The cost of production of the different treatments were Rs 66500 to 86500.The lowest cost was incurred in the control and the highest cost was recorded in weed free (2 hand weeding) treatment. The subsequent higher cost of NRs 85145 was also found in Tembotrione fb 1HW. The benefits ranged from NRs 92090 to 169520 with the maximum and minimum benefit obtained in metribuzin applied as pre emergence fb 1 HW and in the weed free treatment respectively. The next higher benefits of NRs 167590 was obtained in Pendimethalin applied treatment.

Benefit cost ratio (BC) was 1.06 to 2.46 with highest BC ratio obtained from metribuzin applied as pre fb 1 HW while the subsequent higher BC ratio of 2.40 was found in Pendimethalin applied treatment. The lowest BC was in weed free (2 hand weeding) treatment.

CONCLUSIONS

Metribuzin applied as pre emergence at the rate of 0.5 kg a.i ha^{-1} produced the highest grain yield (7.6 Mt ha^{-1}), highest weed control efficiency percentage (77.1) and benefit cost ratio of 2.46. The subsequent higher yield and BC ratio was obtained in Pendimethalin applied as pre emergence at the rate of 1.0 kg a.i ha^{-1}. It is concluded from the experiment that application of Metribuzin as pre emergence at the rate of 0.5 kg a.i ha^{-1} managed the weeds and produced the higher grain yield and economics in maize in the mid–hills condition of Nepal.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the NARC management for approving this projects and the National Agronomy Research team for execution of the experiment. We would like acknowledge highly to Mr Subindra Balami for carrying out the field work.

AUTHORS' CONTRIBUTION

RK Bhattarai conceptualized, conducted and prepared the manuscript as a lead author while other authors assisted in field work and write-up.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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