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Effect of Various Weed Management Practices on Weed Dynamics and Crop Yields under Maize-Wheat Cropping System of Western Hills

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ABSTRACT

Weeds pose a great challenge to cereal farmers and need to be managed before reaching the critical stage. An experiment was conducted to evaluate effect of various weed management practices on the weed dynamics and crop yields under the maize-wheat cropping system in 2019-2020 at research field of Directorate of Agricultural Research, Lumle, Kaski. The experiments consisted of six pre-emergence and post-emergence chemical management practices (Tembotrione post-emergence (PoE), Pendimethalin as pre-emergence (PE), Atrazine as (PoE), Atrazine as PE fb Tembotrione as PoE, Pendimethalin as PE fb 2,4-D Ethyl Ester (EE), Pendimethalin as PE fb Tembotrione as PoE for maize crop; Pendimethalin as PE, Pendimethalin as PE fb Manual weeding, Pendimethalin as PE fb Metribuzin, Pendimethalin as PE fb 2,4-D sodium salt as PoE, 2,4 D sodium salt as PoE, Metribuzin as PoE for wheat crop) compared with manual weeding and weedy check both maize and wheat. These treatments were studied in a randomized complete block design (RCBD) with three replications. *Ageratum conyzoides* and *Chenopodium album* were found to be the major weeds for the maize and wheat crop respectively. Atrazine as pre-emergence fb Tembotrione as post–emergence produced the highest yield (3.575 Mt ha^{-1}) for maize season whereas 4.8 Mt ha^{-1} was obtained in Metribuzin treated plot as post emergence herbicide in wheat growing season. The yield increments by Tembotrione as post emergence was 71.51% and Metribuzin was 63.09% over weedy check. The findings could be useful for researchers and maize-wheat growing farmers of high rainfall ecologies.

Keywords: Crop yield, maize, weed dynamics, wheat, weed management practices,

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INTRODUCTION

Wheat (*Triticum aestivum)* is as the second staple food crop of Nepal (Oli et al 2019) and maize (*Zea mays* L.) is the dominant cereal crop of mid-hills of Nepal. In Nepal, maize and wheat occupied 48.8% of the total cropped area and their productivity is 3.06 and 2.99 Mt ha^{-1} respectively (MOALD 2079). Crop yields are affected by various biotic and abiotic factors like attack of insect and pests, plant nutrients, weeds and growing environment. Among them, presence of weed is one of the factors which lead to high decline in the production in crops.

It is the plant species growing in the domesticated crops that interfere the healthy or normal growth and development of crops and are also known to limit the production of crops causing serious losses in the output of grains, seeds and fruits (Khan et al 2009). Compared to pests, weeds are more responsible for yield reduction in agriculture field **(**Chauhan 2020). Weeds are those notorious yield reducers which compete with the crop plants for light, nutrition, space and many other factors for their growth and development which drastically affect their productions (Cudney et al 2001). Al-Khafji et al (2020) reported the wheat yield reduced loss up to fifty percent while Chikoye and Ekeleme (2003) reported maize yield loss of 20 to 80% by weed infestation. Thapa (2001) reported that heavy rainfall provides weeds favorable environment to grow in flushes. Thapa (2001) reported 97 weeds floras in Pokhara valley in his study in maize field. In Nepal, there are 370 spp. of wheat weeds recorded till now with 54 families and 210 genera. Among them 4 weeds are non-flowering plants and 330 are flowering plants. In flowering plants, 293 are dicots and 73 are monocots (Dangol 2015).

Gandaki province is one of the highest rainfall receiving province and the growth of weeds is fast here. There is very little to no use of chemical weed management practices in this province. Moreover, the studies on weed, its dynamics and the losses caused by it lacks for a cropping system. Hence, this study aims to find out the major weeds causing loss in maize-wheat cropping system and their management techniques compared to manual weeding.

MATERIALS AND METHODS

The experiment was undertaken for two consecutive seasons (spring and winter) in years 2019/20 at research field of the Directorate of Agricultural research (DoAR), Lumle, Kaski, Nepal situated at 1715 masl and between $28^0$17‘58‘‘N and $83^0$49‘03‘‘E. The area of experiment falls under sub-humid climatological region and receives precipitation above 5000mm annually. The weather parameters of the experimental location for the two seasons are presented in Table 1. The table shows maximum temperature (˚C), minimum temperature (˚C), average temperature (˚C), total precipitation (mm) and average soil temperature (˚C at depth of 10-30 cm). The maize sowing was done in May 18, 2019 and wheat was sown in November 24, 2019.

Table 1. Meteorological data observed during the maize and wheat growing seasons in 2019/20

Month of the year 2019/20	Max temp (˚C)	Min temp (˚C)	Average temp (˚C)	Average soil temperature of soil (10-30 cm)	Precipitation (mm)
May, 2019	23.9	14.2	19.1	19.2	250.2
June, 2019	24.4	16.8	20.6	21.6	381.8
July, 2019	23.9	17.7	20.8	22.8	1128.7
August, 2019	25.0	17.7	21.4	23.6	1441.6

Month of the year 2019/20	Max temp (˚C)	Min temp (˚C)	Average temp (˚C)	Average soil temperature of soil (10-30 cm)	Precipitation (mm)
September, 2019	22.8	16.5	19.7	22.3	1149.5
October, 2019	20.9	12.5	16.7	19.8	245.6
November, 2019	19.3	10.4	14.9	17.3	10.0
December, 2019	14.3	4.7	9.5	12.3	55.6
January, 2020	12.7	4.0	8.3	10.3	99.0
February, 2020	14.3	5.5	9.9	11.4	55.7
March, 2020	18.6	8.1	13.3	14.2	83.7
April, 2020	20.7	11.0	15.8	16.9	305.2
May, 2020	21.9	13.9	17.9	19.3	285.5

In maize cropping season (2019/20), during crop sowing month the maximum temperature was 23.9 ˚C, Minimum temperature was 14.2 ˚C, average temperature 19.1˚C, average soil temperature was 19.2˚C and total precipitation of 250 mm. The maize growing season received heavy rainfall throughout its crop duration whereas wheat received uniform rainfall which also affected its flowering and grain filling duration. Highest rainfall was marked in August with 1441.6 mm whereas minimum rainfall was received in November which coincided with sowing period of wheat crop.

Experimental design and treatment details

The Table 2 represents the treatments used in the experiment and herbicide doses respectively. Altogether 8 treatments used in both the experiments for both the seasons. Both the experiments in the consecutive seasons were conducted in Randomized Complete Block Design (RCBD) with three replications.

Table 2. Treatment details used in the experiments

Treatment for maize crop	Doses emergence
Tembotrione post-emergence (PoE)	120 g a.i ha^{-1} as post emergence
Pendimethalin as pre-emergence (PE)	1.0 kg a.i. ha^{-1} as pre-emergence
Atrazine as (PoE)	1.0 kg a.i. ha^{-1} as post-emergence
Atrazine as PE fb Tembotrione as PoE	1.0 kg a.i. ha^{-1} as pre-emergence fb 120 g ha^{-1} as post-emergence
Pendimethalin as PE fb 2,4-D Ethyl Ester (EE)	1.0 kg a.i. ha^{-1} as pre-emergence fb 0.5 kg a.i ha^{-1} as post-emergence
Pendimethalin as PE fb Tembotrione as PoE	1.0 kg a.i. ha^{-1} as pre-emergence fb 120 g kg a.i ha^{-1} as post-emergence
Handweeding @ twice	@ 30 and 45 days
Weedy Check	No weeding done
Treatment for wheat crop	**Doses emergence**
Weed free	Weeding done for three times
Weedy check	No weeding done
Pendimethalin as PE	1.0 kg a.i as pre emergence
Pendimethalin fb Manual weeding	1.0 g a.i as pre emergence
Pendimethalin fb Metribuzin	1.0 kg a.i as pre emergence fb 0.5 kg a.i ha^{-1} as post

Treatment for maize crop	Doses emergence
	emergence
Pendimethalin fb 2,4-D sodium salt as PoE	1.0 kg a.i as pre emergence fb 0.8 kg a.i ha^{-1} as post emergence
2,4 D sodium salt as PoE	0.8 kg a.i ha^{-1} as post emergence
Metribuzin as PoE	0.5 kg a.i ha^{-1} as post emergence

Wheat variety WK 2123 was sown continuously at row distance of 25 cm in a plot size of 16 m^2 (4 m × 4 m). Total number of plots were 24 with net plot size of 384 m^2. The individual plot size for maize experiment was 12 m^2. The row spacing for maize was 75 cm accommodating 4 lines per plot and the variety used was Ganesh-2. The crop was grown in rainfed condition. Fertilizer application was done at 120:60:40 kg NPK $ha^{-1}$for both maize and wheat. Total phosphorous and potassium was applied at basal dose while nitrogen was applied at two split doses, half as basal dose and another half dose was top dressed at time of second weeding in both cropping seasons. Muriate of Potash (MOP,0:0:60) was applied as source of potassium, Diammonium Phosphate (DAP, 18:46:0) was applied as source of phosphorous and urea and DAP was applied as source of nitrogen

A quadrate of 1 m^2 was placed randomly at each plot for weed density and weed fresh weight measurement in wheat and maize respectively. Thus, collected weeds were initially sundried and later oven dried at 64˚C for 72 hours till the dry weight was constant. The dry weight was expressed as g m^{-2}. At harvest, maize was harvested manually and grains well shelled in power operated corn sheller. In case of wheat, it was manually harvested and later threshed with power operated thresher. Frequency percentage of weeds was calculated using the formula given by Travlos et al (2018).

$$\text{Frequency (\%)} = \frac{\text{number of quadrates in which target species occurred}}{\text{total number of quadrates}} \times 100$$

All the raw data was entered in MS Excel and data was analyzed in ADEL-R software at 0.05%

RESULTS AND DISCUSSION

Weeds of maize and wheat field

The weeds from the maize and wheat field were studied and 12 major weeds of maize and wheat field were enumerated in the table no 3 and 4 respectively. The table enlist their botanical name, common name, their native name in Nepali language, their respective family and their habit of growing season and frequency percentage.

Table 3. Major weeds and their frequencies (%) in maize

SN	Nepali name	Botanical name	Common name	Family	Freq %
1	Abhijalo	*Drymaria cordata*	Tropical chickweed	Caryophyllaceae	75.0
2	Armale	*Anagallis arvensis*	Red chickweed	Primulaceae	87.5
3	Sano kane jhar	*Commelina diffusa*	Bengal dayflower	Commelinaceae	79.2
4	Badmale	*Polygonum convolvulus*	Wild buckwheat /Black bindweed	Polygonaceae	79.2
5	Bhiringi jhar	*Alternanthera sessilis*	Sisoo spinach	Amaranthaceae	75.0
6	Chari amilo	*Oxalis corniculata*	Creeping woodsorrel	Oxalidaceae	66.7

SN	Nepali name	Botanical name	Common name	Family	Freq %
7	Clover	*Trifolium repens*	Dutch clover	Fabaceae	66.7
8	Dubo	*Cynodon dactylon*	Bermuda grass	Poaceae	91.7
9	Gandhe/boke /Hanumane	*Ageratum conizoides*	Goatweed	Asteraceae	100.0
10	Kode ghas	*Elusine indica*	Indian goosegrass	Poaceae	75.0
11	Latte	*Amaranthus viridis*	Slender amaranth	Amaranthaceae	70.8
12	Mothe	*Cyperus rotundus L.*	Nut grass	Cyperaceae	70.8

Table 4. Major weeds and their frequencies (%) in wheat

SN	Nepali name	Botanical name	Common name	Family	Freq %
1	Akara	*Vicia hirusta*	Hairy vetch	Fabaceae	70.8
2	Armale	*Anagallis arvensis*	Red chickweed	Primulaceae	50.0
3	Bethe	*Chenopodium album*	White goosefoot /Lamb's quarter	Amaranthaceae	100.0
4	Bukiful	*Otanthus marimatus*	Cotton weed	Asteraceae	75.0
5	Clover	*Trifolium repens*	Dutch clover	Fabaceae	66.7
6	Gandhe/boke/ Hanumane	*Ageratum conizoides*	Goatweed	Asteraceae	91.7
7	Jaighas	*Avena fatua*	Wild oat	Poaceae	62.5
8	Kuro	*Bidens pilosa*	Hitch-hikers/Black jack	Asteraceae	62.5
9	Mothe	*Cyperus rotundus L.*	Nut grass	Cyperaceae	66.7
10	Ragate jhar	*Phalaris minor*	Little seed canary grass	Poaceae	83.3
11	Sukul jhar	*Polygonum plebeium*	Common knotweed	Polygonaceae	70.8
12	Thange jhar	*Spergula arvensis*	Corn spurry	Caryophyllaceae	95.8

The major weeds when studied for the maize and wheat cropping season depending upon their frequency percentage, major yield limiting weeds were *Ageratum conyzoides* and *Chenopodium album* respectively. The weed density, abundance and dominance change with time, weather, seed bank in soil and moisture status of the soil. *Anagallis arvensis, Trifolium repens, Ageratum conyzoides* and *Cyperus rotundus* were the only weeds that were present in both crops whereas other weeds were abundant in only one crop season. This shows how weeds are season specific and crop bound owing to their dynamism.

Density and dry matter accumulation of weeds

Method of weed control influenced the density and dry matter accumulation of weeds (Table 5). In maize season, the highest weed count was recorded in weedy check (161.67 m^{-2}) and was the lowest in Atrazine as PE fb Tembotrione as PoE (24.67 m^{-2}). The fresh weight and dry weight also followed the similar trend. The second best options in terms of weed density, fresh weight and dry weight was manual weeding twice in one cropping season. The differences in the weed density, fresh weight and dry weight were significant among the treatments in maize.

Similarly, in case of wheat growing season, Metribuzin as PoE application had significantly the lowest weed density of 60.0 m^{-2}, fresh weight (53.17 g m^{-2}) and dry weight (11.66 g m^{-2}) which was at par with weedfree condition. Weedy check had the highest presence of weed number (373 m^{-2}) as well as fresh weight (453.68 g m^{-2}) and dry weight (86.35 g m^{-2}).

Table 5. Weed density, weed fresh weight and oven dry weight of maize as affected by various weed management practices at Lumle, Kaski, 2019-2020

Treatments	Weed density (m^{-2})	Fresh weight (g m^{-2})	Dry weight (g m^{-2})
Tembotrione as PoE @ 120 g ha^{-1}	6.67 (44.33)	9.36 (87.53)	3.91 (15.73)
Pendimethalin as PE @ 1 kg a.i ha^{-1}	8.83(78.00)	12.79 (165.63)	7.02 (50.16)
Atrazine as PoE @1 kg a.i ha^{-1}	9.82 (96.33)	14.49 (210.40)	8.35 (69.97)
Atrazine as PE @1 kg a.i ha^{-1} fb Tembotrione as PoE @ 120 g ha^{-1}	4.98 (24.67)	7.74 (59.67)	3.69 (13.44)
Pendimethalin as PE @1 kg a.i. ha^{-1}fb 2,4-D EE as PoE @0.5 kg a.i ha^{-1}	8.18 (67.67)	11.30 (130.50)	6.40 (42.17)
Pendimethalin as PE @1 kg a.i. ha^{-1} fb Tembotrione as PoE @ 120 g ha^{-1}	7.63 (58.33)	11.02 (121.97)	6.07 (36.62)
Handweeding @ two times	5.86 (34.00)	8.21 (68.30)	4.35 (18.71)
Weedy Check	12.65 (161.67)	18.62 (347.77)	11.04 (121.79)
Mean	**8.08**	**11.69**	**6.35**
LSD (0.05)	1.771	2.695	2.022
CV (%)	12.52	13.16	18.18

Note: Figure in parentheses denotes the square root transformed values

Table 6. Weed density, weed fresh weight and oven dry weight of wheat as affected by various weed management practices at Lumle, Kaski, 2019-2020

Treatments	Weed density (m^{-2})	Fresh weight (g m^{-2})	Dry weight (g m^{-2})
Weedfree	7.76 (64.7)	9.36 (49.03)	3.05 (9.78)
Weedy check	19.18 (373.0)	12.79 (453.68)	9.3 (86.35)
Pendimethalin as PE @ 1 kg a.i ha^{-1}	8.51 (77.0)	14.49 (110.42)	3.55 (12.68)
Pendimethalin as PE @ 1 kg a.i ha^{-1} fb Manual weeding	8.49 (78.0)	7.74 (41.74)	2.69 (7.23)
Pendimethalin as PE @ 1 kg a.i ha^{-1} fb Metribuzin @ 0.5 kg a.i ha^{-1}	6.23 (39.7)	11.3 (28.52)	2.46 (5.72)
Pendimethalin as PE @ 1 kg a.i ha^{-1} fb 2,4 D-NA @ 0.8 kg a.i ha^{-1}	6.79 (47.0)	11.02 (29.33)	2.41 (5.76)
2-4D Na Salt @ 0.8 kg a.i ha^{-1}	12.52 (158.0)	8.21 (153.44)	5.06 (27.85)
Metribuzin PoE @ 0.5 kg a.i ha^{-1}	7.58 (60.0)	18.62 (53.17)	3.38 (11.60)
Mean	**9.63**	**11.69**	**3.99**
LSD (<0.05)	4.027	2.695	1.985
CV (%)	23.87	13.16	28.43

Note: Figure in parentheses denotes the square root transformed values

Crop phenology, yield and yield attributes for maize crop

Variation was not found for crop phenology, growth parameters but found in crop yield. No significant differences in the crop phenology might be due to the use of same variety Ganesh-2 in maize experiment. Hand weeding gave the highest plant height of 190 cm. Though insignificant, the highest thousand kernel weight was observed in Atrazine as PE fb Tembotrione as PoE (0.417 kg) and lowest in weedy check (0.346 kg). Significantly higher grain yield of 3.575 Mt ha^{-1} was found in Atrazine as PE fb Tembotrione as PoE followed by twice handweeding (3.501 Mt ha^{-1}). Similar result was also found by Shrestha et al (2021). In another experiment done in the mid hills of Nepal, the grain yield decreases in maize fields due to the weed infestation under farmer‘s management practices was found to be 1.985 Mt ha^{-1} in Baglung and 1.760 Mt ha^{-1} in Parbat districts (Karki et al 2014). The result is in conformity that

weedy environment in maize results in significant yield reduction. Both the treatments with significantly higher yield had periodic weed management be it hand weeding or chemical management over other treatments which ensured the weed free condition during the critical period of crop-weed competition (Hall et al 1992).

Table 7. Crop phenology, yield and yield attributes of maize as affected by various weed management practices at Lumle, 2019-2020

Treatments	Days to 50% tasselling	Days to 50% silking	Plant to cob ratio	Plant height (cm)	Grain yield (Mt ha^{-1})	Thousand kernel weight (kg)
Tembotrione as PoE @ 120 g ha^{-1}	79.7	83.0	1.15	187.00	3.085	0.374
Pendimethalin as PE @ 1 kg a.i ha^{-1}	79.0	81.7	1.31	159.47	2.262	0.347
Atrazine as PoE @1 kg a.i ha^{-1}	79.3	82.0	1.18	172.00	2.188	0.363
Atrazine as PE @1 kg a.i ha^{-1} fb Tembotrione as PoE @ 120 g ha^{-1}	79.3	82.0	1.12	175.67	3.575	0.417
Pendimethalin as PE @1 kg a.i ha^{-1} fb 2,4-D EE as PoE @0.5 kg a.i ha^{-1}	80.0	82.7	1.10	175.40	2.468	0.374
Pendimethalin as PE @1 kg a.i. ha^{-1} fb Tembotrione as PoE @ 120 g ha^{-1}	79.7	82.3	1.05	182.80	3.075	0.363
Hand weeding @ two times	79.3	81.7	1.11	190.67	3.501	0.363
Weedy Check	79.7	83.3	1.09	168.60	2.085	0.346
Mean	**79.5**	**82.33**	**1.14**	**176.45**	**2.780**	**0.369**
LSD (<0.05)	ns	ns	ns	ns	0.771	ns
CV (%)	1.30	1.11	9.37	13.50	15.84	8.81

Table 8. Crop phenology, yield and yield attributes of wheat as affected by various weed management practices at Lumle, Kaski, 2019-2020

Treatments	Days to 50% anthesis	Days to 80% Physiological maturity	Plant height (cm)	Spike number/m2	Spike length (cm)	Thousand kernel weight (g)	Adjusted grain yield @12% moisture content
Weedfree	129	181.7	98	273	10.02	37.5	4.937
Weedy check	129.3	181.7	95	216	9.5	31.4	3.026
Pendimethalin	129.7	181.7	92.6	271	10.27	35.7	3.522
Pendimethalin fb Manual weeding	128.7	181.3	93.6	259	10.6	35.7	4.576
Pendimethalin fb Metribuzin	129	181.3	87.7	226	10.48	35.6	4.651
Pendimethalin fb 2,4 D-NA	129.7	181.3	88.8	259	9.9	33.8	4.122
2-4D Na Salt	129	181.3	84.5	275	10.17	32.3	3.28
Metribuzin PoE	129	181	94.5	277	10.17	36.6	4.89
Mean	129.2	181.4	91.84	257	10.14	34.82	0.183
LSD(<0.05)	ns	ns	ns	31.912	ns	3.073	0.729
CV(%)	0.933	1.315	5.34	7.091	7.284	5.039	10.12

Days to 50% anthesis and 80% physiological maturity didn't show any significant differences. The average days taken to 50% anthesis and 80% physiological maturity were 129.2 and 181.4

days respectively. Though insignificant, plant height was maximum for weed free plot followed by weedy check plot minimum for 2,4-D treated plot followed by pendimethalin fb 2,4-D treated plot during first year. Safdar et al (2011) stated plant height as a varietal governed trait and difference in plant height within a different agronomic practice might not be reflected properly. However, wider spacing or crop management practices that favor less crop- weed competition might favor a better vegetative growth leading to taller plants which was evident in our experiment too.

Among the yield attributes, only spike number per meter square was significantly influenced among the treatments. Spike length and thousand kernel weight didn't differ significantly. The highest spike number per meter square was observed in Metribuzin as PoE (277) followed by 2-4 D Na Salt as PoE and weed free condition. Though insignificant, highest spike length was achieved in treatment Pendimathalin fb manual weeding (10.60 cm) but higher thousand kernel weight was observed in weed free condition (37.5 g). Grain yield is the ultimate result of yield attributing component. Maximum grain yield was obtained in weed free treatment (4.937 Mt ha^{-1}) in followed by Metribuzin (4.890 Mt ha^{-1}) whereas weedy check had lowest yield. The result showed decreasing yield with increasing weed pressure in each treatment. This was found in conformity with Weiner et al (2001) who found a simple negative linear relationship between yields and weed biomass when there was high weed pressure in the experimental plots. Higher grain yield was attributed to the higher number of effective tillers and high test weight contributed by better weed management practices. Safdar et al (2011) found greater wheat yields in plot where the chemical weed management practices were used and treatment with highest reduced weed competition had the highest grain yield.

CONCLUSIONS

Use of Atrazine as PE @1 kg a.i ha^{-1} fb Tembotrione as PoE @ 120 g ha^{-1} in maize and Metribuzin as PoE @ 0.5 kg a.i ha^{-1} in wheat is the best chemical management options in mid-hill condition which could be achieved at par by manual weeding. Because of the scenario of shortage of labour and increasing cost of labour, the adoption of chemical management may be one viable option for farmers for weed management in their fields.

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AUTHORS' CONTRIBUTION

R Acharya conducted the experiment, generated data and analysed them and wrote the manuscript. Other authors supervised and edited the manuscript.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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