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Herbicide application improved weed control and yield in Bajra Napier Hybrid

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ABSTRACT

Weeds impair the production and quality of forage crops. A research was performed to assess the PE application of oxadiargyl and sequential application of oxadiargyl PE fb 2,4-D POE for weed control, microbial and enzymatic activity, and yield in Bajra Napier hybrid (BN hybrid; *Pennisetum glaucum* × *Pennisetum purpureum*). Weed density, microbial count, dehydrogenase (DHA) activity and yield data were recorded during 2015 and 2016 rainy season. The data from this study indicated dominant weed flora of the experimental site was *Commelina benghalensis* (13%), *Echinochloa colona* (28%), *Cyperus rotundus* (30%) and other weeds (29%). Plots treated with oxadiargyl pre-emergence (PE) had lower density and biomass of *Echinochloa colona, Cyperus rotundus* and total weeds at 25 days after planting (DAP); similar trend was also observed at 50 DAP. However, lower density of *Commelina benghalensis* and other weeds were recorded in oxadiargyl PE fb 2,4-D POE treated plots compared to oxadiargyl PE at 50 DAP, due to ability of 2,4-D on controlling broadleaved weeds. A similar green fodder (GF) and dry fodder (DF) yield was recorded in oxadiargyl PE and oxadiargyl PE fb 2,4-D POE. Weed control treatment evaluation indices including weed control efficiency (WCE), herbicide efficiency index (HEI) and weed index (WI) also showed no difference among herbicide treatments with respect to total weed control and crop yield. Weed management in BN hybrid either using oxadiargyl PE or oxadiargyl PE fb 2,4-D POE provide an effective weed control and better yield.

Key words: Dehydrogenase, Green fodder yield, Herbicide efficiency index, Microbes, Weed control efficiency, Weed index

The sustainability of livestock sector is dependent on the year round availability of cattle feeds and quality forages. In India, the year round fodder requirement is being managed through cultivation of perennial forage crops such as Bajra Napier hybrid (BN hybrid; *Pennisetum glaucum* × *Pennisetum purpureum*), guinea grass (*Megathyrsus maximus* Jacq.), and Tri Specific Hybrids (*Pennisetum purpureum* × *Pennisetum squamulatum* × *Pennisetum glaucum*). The BN hybrid is high yielding (70 to 290 t/ha), palatable, and adaptable to different weather and soil condition (Faruqui *et al.* 2009). However, the wider row to row spacing (1 m) and slower growth at the initial stage makes the grass (BN hybrid) more vulnerable to weed competition (Prabhu *et al.* 2016). Early season weeds; further, grow profusely and suppress the slow growing BN hybrid (Gill and Tiwana 2018).

The degree of forage yield and quality loss in BN hybrid is dependent on the duration of crop-weed competition (Gill and Tiwana 2018). The critical period for weed control in BN hybrid was varied according to planting method (4 to 32 days for rooted slips and 5 to 27 days for stem cutting) (Gill *et al.* 2016). This clearly indicates the necessity of managing the fields free from weeds up to 35 to 40 days after planting. For that, the growers should keep the field weed free either using integrated weed management [pre application (PE) of herbicide followed by (fb) mechanical or hand weeding] or sequential application of herbicides [PE fb post application (POE) herbicides].

Therefore, our focus in this study was to compare the effect of PE application of oxadiargyl alone with sequential application of oxadiargyl PE fb 2,4-D POE at recommended dose on weed control, microbial and dehydrogenase activity, and yield in BN hybrid. The hypotheses of this experiment were (1) Sequential application of PE and POE application of herbicides will be more efficient in controlling weeds without affecting the microbial activity compared to only PE application of herbicide, and (2) Both treatments will be identical in weed control, microbial activity and BN hybrid yield.

MATERIALS AND METHODS

Study site and treatments

The field experiment was established at the Indian

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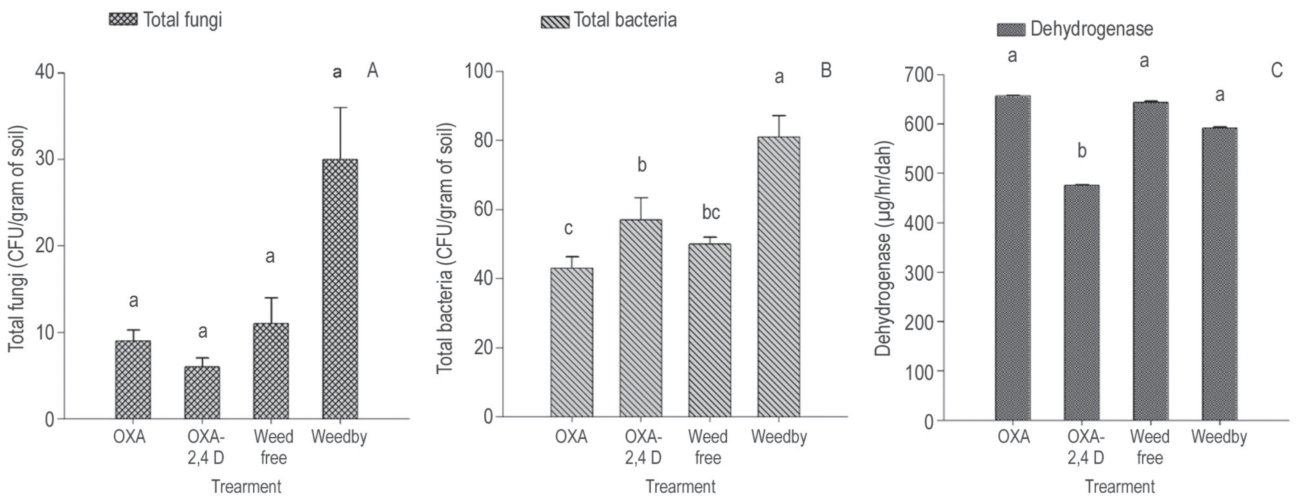

Fig 1 Influence of weed management treatments on the soil bacterial (A) and fungal (B) count, and dehydrogenase activity (C) in Bajra Napier hybrid.

Grassland and Fodder Research Institute (IGFRI) in Jhansi, UP (25°31′, 21.4 ″N and 78°33′, 48.2″E) during the rainy season of 2015 and 2016. The soil type of the experimental site was sandy clay loam with pH 6.6, 110 kg/ha N, 17.02 kg/ha P_2O_5 and 197.12 kg/ha K_2O. The treatments consisted of oxadiargyl (PE; 0.09 kg/ha), oxadiargyl (PE; 0.09 kg/ ha) fb 2, 4-D (Ethyl Ester; POE; 1.0 kg/ha), weed free plot and weedy plot with 5 replications, and organized in a randomized complete block design (RCBD). The plot size was 5m × 4m (0.002 ha). The PE herbicide was applied at 3 to 5 days after planting (DAP) of BN hybrid and POE herbicide was applied at 25 to 30 DAP using a battery operated sprayer. Tillage practices for the planting of BN hybrid included disking (15 cm depth), moldboard ploughing (20 cm depth) followed by harrowing (using 9 tynes cultivator). The rooted slips of BN hybrid were planted with a row to row spacing of 1m × 1m. Irrigation was given at 10 to 15 days interval during March and April months. However, irrigation was not applied during the winter (dormant growth) and monsoon season. Fertilizer N, P_2O_5 and K_2O were applied through urea, single super phosphate and muriate of potash at 60, 50 and 40 kg/ha, respectively, at the time of planting in both the years. The remaining 90 kg of N were applied as split (30 kg/ha N per cut) after every cut. Harvesting of GF was done at 55 to 60 days after planting and subsequent cuts were taken at 30 to 35 days after the first cut of BN hybrid.

Weather data

Long-term average rainfall of the location during rainy season (June to October) is 868.8 mm. Total rainfall received in 2015 growing season was 33% lesser than the 2016. It was also lesser (39%) than the long-term average rainfall of the location during rainy season. Mean annual maximum and minimum air temperature were almost similar during both the crop season.

Weed density and dry weight estimation

Weed species identification and counting were done at 25 and 50 DAP in a randomly placed quadrate in each treatment. Four number of quadrates (0.25 m^2) per plot were used to study the weed dynamics. At the time of weed counting, species-wise biomass were collected to estimate the dry weight of individual weed species. The collected weed biomass were kept air dry and then placed in a hot air oven at 65°C for 72 hr to get the dry matter weight of weeds. Weed density, dry matter weight and crop yield from the treatments and control (weed free and weedy plot) were used to estimate the weed control efficiency (WCE, Mani *et al.* 1973), weed index (WI, Gill 1969) and herbicide efficiency index (HEI, Krishnamurty *et al.* 1975).

Soil microbial population and dehydrogenase estimation

The random soil samples were taken from 0 to 15 cm depth after second harvest of BN hybrid (90 DAP) to account the impact of both PE and POE applied herbicides on soil microbial parameters. The standard dilution plate technique was carried out to enumerate the total bacterial and fungal population. The 10 g of air-dried soil were added to 90 mL of sterile distilled water. After homogenization in a mechanical shaker for 30 min, the solution then diluted for bacteria (10^7) and fungi (10^4), and resulting solution (aliquots) was plated in a selective culture media [total bacteria - Nutrient Agar (Waksman 1922) and total fungi - Czapek-Dox Agar; (Thom and Raper 1945). The agar plates (3 replications); further, incubated at 28°C for up to 2 days for bacteria, and 7 days for fungi and the colony forming units (CFU) were counted in a digital colony counter.

Soil dehydrogenase activity (DHA) was quantified using Triphenyl Tetrazolium Chloride (TTC) method described by Casida *et al.* (1964). The 1 g of air-dried soil was incubated at 28±0.5°C in 0.2 mL of 3% TTC and 0.5 mL of water for 24 hr. During the incubation the colour less TTC is reduced by dehydrogenase enzyme in the soil, a red colour insoluble product Triphenyl Formazan (TPF) is formed. Further, the quantity of TPF formed at the end 24 hr of incubation was trapped in methanol (10 mL) and quantified calorimetrically (spectrophotometer) at 485 nm wavelength and compared with the standard TPF. The DHA then expressed in µg TPF formed /hr/day.

Fodder yield measurement

The crop was harvested at 65, 95 and 125 DAP as per the recommendation of IGFRI, Jhansi. At harvest, two 1 m^2 area in each plot were harvested to calculate the green fodder (GF) yield of BN hybrid. Similarly, 100 g of GF from each plot were collected and placed in shade for air-drying, and then the air-dried samples were placed in a hot air oven at 65°C for 72 hr to estimate the dry fodder yield (DF). The final GF and DF yield is expressed in t/ha.

Statistical analysis

Data normality (Shapiro-Wilk test) was checked before performing the analysis of variance (ANOVA). Weed density and dry matter weight data were subjected to transformation ($\sqrt{X+1}$) to nullify the skewness of the data. Treatment was considered as a fixed effect in the model, while the year and replication were considered as the random effects. ANOVA were performed using the Proc GLIMMIX procedure in SAS (SAS Institute Inc, Cary, NC) and means separation were done using the t-test comparison between two groups ($\alpha = 0.05$). Proc TTEST was used to perform the pairwise comparison ($\alpha = 0.05$) between two herbicides treatment effect on WCE and HEI.

RESULTS AND DISCUSSION

Weed density and biomass

Treatment -by- days after planting (DAP) interaction was significant for the density and biomass of *Commelina benghalensis, Echinochloa colona, Cyperus rotundus,* other weeds and total weeds in BN hybrid ($p<0.05$). Therefore, analysis of data were separated by DAP (25 and 50 DAP). The research plots at Jhansi were infested with mixed weed flora in both the year of the study. The weed flora of the study site comprised of 13% *Commelina benghalensis,* 28% *Echinochloa colona,* 29% other weeds (*Catharanthus pusillus,Cleome gynandra, Celosia argentea, Cynodon*

Table 1 Treatment effect at 25 and 50 DAP on weed count (No./m^2) in Bajra Napier hybrid

Treatment	Weed count at 25 DAP[a]					Weed count at 50 DAP				
	Commelina benghalensis	*Echinochloa colona*	*Cyperus rotundus*	Others[b]	Total[c]	*Commelina benghalensis*	*Echinochloa colona*	*Cyperus rotundus*	Others	Total
Oxadiargyl	8.0 (64)a	8.2 (68)b	8.7 (76)b	10.7 (115)a	18.0 (323)b	8.2 (68)a	10.2 (106)b	6.6 (44)b	11.8 (138)a	19.0 (356)b
Oxadiargyl fb 2,4-D EE*	7.8 (61)a	7.6 (59)b	8.5 (73)b	10.8 (117)a	17.6 (310)b	4.2 (18)b	10.1 (104)b	6.3 (40)b	6.2 (39)b	14.0 (201)b
Weed free	1.0 (1)b	1.0 (1)c	1.0 (1)c	1.0 (1)b	1.0 (1)c	1.0 (1)c	1.0 (1)c	1.0 (1)c	1.0 (1)c	1.0 (1)c
Weedy check	8.6 (74)a	10.5 (110)a	16.5 (275)a	12.3 (153)a	24.7 (612)a	8.4 (72)a	12.6 (161)a	12.6 (161)a	12.5 (158)a	23.0 (552)a

*Efficacy of oxadiargyl only evaluated at 25 days after planting (DAP). [a]Weed count data were transformed using square-root ($\sqrt{x+1}$) before performing ANOVA and the original values of weed count mentioned in the parenthesis. [b]*Digera arvensis, Catharanthus pusillus, Leucas aspera, Cleome gynandra, Celosia argentea, Cynodon dactylon,* and *Digitaria sanguinalis*. [c]Means followed by different letters are significant ($p < 0.05$).

Table 2 Treatment effect at 25 and 50 DAP on weed biomass (g/m^2) in Bajra Napier hybrid

Treatment	Weed biomass at 25 DAP[a]					Weed biomass at 50 DAP				
	Commelina benghalensis	*Echinochloa colona*	*Cyperus rotundus*	Others[b]	Total[c]	*Commelina benghalensis*	*Echinochloa colona*	*Cyperus rotundus*	Others	Total
Oxadiargyl	1.3 (1.6)a	2.3 (5.4)b	2.8 (7.8)b	3.6 (12.8)b	5.2 (27.6)b	3.8 (14.7)a	3.8 (14.2)b	2.8 (7.7)b	4.0 (15.6)b	7.2 (52.2)b
Oxadiargyl fb 2,4-D EE*	1.3 (1.7)a	2.3 (5.4)b	2.8 (7.7)b	3.6 (13.2)b	5.3 (28.1)b	2.4 (6.0)b	3.9 (14.9)b	3.0 (8.8)b	3.7 (13.5)b	6.6 (43.2)b
Weed free	1.0 (1)b	1.0 (1)c	1.0 (1)c	1.0 (1)c	1.0 (1)c	1.0 (1)c	1.0 (1)c	1.0 (1)c	1.0 (1)c	1.0 (1)c
Weedy check	1.3 (1.6)a	5.0 (25.9)a	5.8 (33.6)a	5.0 (25.4)a	9.3 (86.6)a	3.9 (14.8)a	7.1 (50.9)a	5.7 (33.5)a	5.2 (27.6)a	11.2 (126.8)a

*Efficacy of oxadiargyl only evaluated at 25 days after planting (DAP). [a]Weed biomass data were transformed using square-root ($\sqrt{x+1}$) before performing ANOVA and the original values of weed count mentioned in the parenthesis. [b]*Digera arvensis, Catharanthus pusillus, Leucas aspera, Cleome gynandra, Celosia argentea, Cynodon dactylon,* and *Digitaria sanguinalis*. [c]Means followed by different letters are significant ($p < 0.05$).

dactylon, Digera arvensis, Digitaria sanguinalis and *Leucas aspera*) and 30% *Cyperus rotundus*.

At 25 DAP, we assessed the efficacy of only PE applied herbicide on weed control (Table 1&2). The application of oxadiargyl (PE) decreased the density of *Echinochloa colona* (38%), *Cyperus rotundus* (72%) and total weeds (47%) compared to weedy check, except the density of *Commelina benghalensis* and other weeds (Table 1). Likewise, oxadiargyl treated plots recorded a dry biomass weight of *Echinochloa colona* (5.4 g/m^2), *Cyperus rotundus* (7.7 g/m^2) and total weeds (28.1 g/m^2) which was considerably lower than the weedy check (25.9, 33.6 and 86.6 g/m^2, respectively) at 25 DAP (Table 2). The results are in agreement with the findings of Singh *et al.* (2016), who reported that PE application of oxadiargyl reduced the density of grass (16 to 23 plants/m^2), broadleaved (7 to 8 plants/m^2) and sedges (2 to 3 plants/m^2) compared to weedy check (51, 19 and 7 plants/m^2, respectively) in rice. Thus, the results from this study revealed that effective herbicide for PE in BN hybrid at Jhansi was oxadiargyl because of its broad-spectrum control of weeds.

The efficacy of both PE and POE applied herbicides on weed control was assessed at 50 DAP (Table 1 and 2). The density of *Commelina benghalensis* and other weeds were 18 and 39 number/m^2 in sequential application of oxadiargyl PE fb 2,4-D POE, respectively, whereas the density was 68 and 138 number/m^2 in only PE applied oxadiargyl plots, respectively (Table 1). However, PE application of oxadiargyl and sequential application of oxadiargyl PE fb 2,4-D POE had an identical effect on the density of *Echinochloa colona*, *Cyperus rotundus* and total weeds. At 50 DAP, biomass of *Echinochloa colona*, *Cyperus rotundus*, other weeds and total weeds were not varied between PE applied oxadiargyl and sequential application of oxadiargyl PE fb 2,4-D POE (Table 2) whereas, the sequential application of oxadiargyl PE fb 2,4-D POE had a lower biomass weight of *Commelina benghalensis* (6.0 g/m^2) compared to PE applied oxadiargyl (14.7 g). Overall, this study showed that both PE application of oxadiargyl and sequential application of oxadiargyl PE fb 2,4-D POE were effective to control *Echinochloa colona*, *Cyperus rotundus* and total weeds at 25 and 50 DAP in the BN hybrid. Furthermore, weed control efficiency (WCE) and herbicide efficiency index (HEI) data also showed that there was no difference between PE application of oxadiargyl and the sequential application of oxadiargyl fb 2,4-D in respect to overall weed control. However, the areas with high density of *Commelina benghalensis, Digera arvensis, Catharanthus pusillus, Leucas aspera, Cleome gynandra* and *Celosia argentea,* POE application of 2,4-D can be a viable option.

The data on total fungi, bacteria and DHA are shown in Fig 1. The herbicide treatments affected the total bacterial count, and DHA, except total fungi count (Fig 1 A). The fungi count was varied from 6 to 30 CFU/ g soil, the maximum number of fungi was observed in weedy plot (30 CFU/g soil) compared to other treatments, though they are not significant (p>0.05). However, the application of oxadiargyl (PE) and sequential application of oxadiargyl PE fb 2,4-D POE decreased the bacterial number (43 and 57 CFU/g soil, respectively) compared to weedy check plot (81 CFU/g soil). Likewise, weed free plot also had a lower number of bacteria (50 CFU/g soil) compared to weedy check plot (Fig 1 B). Similar results were observed by Sathiyavani *et al.* (2015) who reported the application of oxadiargyl PE (0.25 kg/ha) decreased soil bacteria and fungi count by 8 to 9% compared to weedy check in turmeric.

In the case of soil DHA, weed management practices resulted in higher activity, except in the sequential application of oxadiargyl PE fb 2,4-D POE, range was varied from 476 to 657 µg/hr/day (Fig 1 C). The highest activity of DHA was recorded in PE applied oxadiargyl (644 µg/hr/day) whereas; the lowest was documented in the sequential application of oxadiargyl PE fb 2, 4-D POE (476 µg/hr/day). Thus, the study revealed that weed management practices such as oxadiargyl, sequential application of oxadiargyl fb 2, 4-D and weed free plot influenced the bacterial population and DHA activity compared to weedy plot. Further, keeping weeds throughout crop season recorded a higher number of fungi (P<0.05), bacteria and DHA activity compared to other treatments. This is probably due to production of root exudates and availability of suitable associated plants by keeping plots weedy. Therefore for higher microbial and biochemical activity maintaining weeds below the threshold level (not complete control) is important.

Green and dry fodder yield

In the both years of study PE application of oxadiargyl (9.6 and 1.75 t/ha) and sequential application oxadiargyl fb 2,4-D POE (9.8 and 1.75 t/ha) recorded similar GF and DF yield, respectively. However, weed free plot recorded higher yield (11 and 2 t/ha) compared to PE applied oxadiargyl treatment, whereas it was on par with sequential application of oxadiargyl PE fb 2,4-D. These data showed that either application of oxadiargyl (PE) or sequential application of oxadiargyl PE fb 2,4-D POE can give a good yield of BN hybrid. The data on the weed index (WI), further, indicated that there was no difference among oxadiargyl (PE) or sequential application of oxadiargyl PE fb 2,4-D POE treated plots, in terms of yield loss compared to weed free plot, the range is being 9.3 to10.3%. However, broadleaved weeds such as *Commelina benghalensis, Digera arvensis, Catharanthus pusillus, Leucas aspera, Cleome gynandra* and *Celosia argentea* in BN hybrid may not control by the application of oxadiargyl because it is not labelled for controlling those weeds. Therefore, POE application of 2,4-D could be an effective option for growers to control some of these broadleaved weeds in BN hybrid.

Conclusions

In BN hybrid, the oxadiargyl PE and sequential application of oxadiargyl PE fb 2,4-D significantly reduced the weed density and biomass by 47 to 64% and 59 to 68%, respectively. Both the herbicide treatments were effective on controlling *Echinochloa colona*, *Cyperus rotundus* and total weeds at 25 and 50 DAP. 2,4-D POE application was more efficient on *Commelina benghalensis* and other weeds (*Digera arvensis, Catharanthus pusillus, Leucas aspera, Cleome gynandra* and *Celosia argentea*) compared to only PE application of oxadiargyl at 50 DAP. Oxadiargyl PE has reduced bacterial count compared to sequential application of oxadiargyl PE fb 2,4-D POE, whereas DHA activity was lower in the later treatment. Fungi count, however, did not affected by herbicide treatments. Both herbicide treatments recorded similar BN hybrid yield. Therefore, for obtaining optimum crop yield and efficient control of weeds in BN hybrid growers can use either oxadiargyl PE or sequential application of oxadiargyl PE fb 2,4-D POE. However, 2,4-D POE can be more effective under over dominance of broadleaved weeds such as *Commelina benghalensis*, *Digera arvensis, Catharanthus pusillus, Leucas aspera, Cleome gynandra* and *Celosia argentea*, because oxadiargyl PE has no effect on these weeds. Hence, selection of either oxadiargyl PE or sequential application of oxadiargyl PE fb 2,4-D POE will be depending on the spectrum of weed population in BN hybrid.

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