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Screening of herbicides for effective weed control in Bajra Napier hybrid

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Abstract

A field experiment was conducted to study the selectivity of herbicides to Bajra Napier hybrid (*Pennisetum glaucum× Pennisetum purpureum*) during 2013-14 and 2014-15. The data indicated that 63.15 and 46.51% more green forage yield was obtained in weed free crop followed by 39.37 and 29.04% in oxadiargyl at 0.09 kg a.i. ha^{-1} at 3-5 days after planting (DAP) fb 2, 4 D EE at 1 kg a.i. ha^{-1} at 20-25 DAP over weedy check in 2013-14 and 2014-15, respectively. The higher weed control efficiency (75%) and weed control index (75.5), and the lowest weed index (17.36) was found with the application of oxadiargyl at 0.09 kg a.i. /ha at 3-5 (DAP) fb 2, 4 D EE at 1 kg a.i. /ha at 20-25 DAP. It was, therefore, quite obvious from the experimental findings that oxadiargyl @ 0.09 kg a.i. /ha at 3-5 (DAP) followed by 2, 4 D EE@ 1 kg a.i./ha can safely replace the laborious, time consuming and costly hand weeding.

Keywords: Bajra Napier hybrid, Herbicides, Phytotoxicity, Screening, Weed control efficiency

Abbreviations: **DAP:** Days after planting; **POE:** Post-emergence; **PRE:** Pre-emergence

Introduction

Bajra Napier hybrid (*Pennisetum glaucum* x *Pennisetum purpureum*) is a perennial, erect growing, nutritious, high yielding grass and suitable for cultivation under varying agro-climatic and soil conditions (Gupta and Mhere, 1997). In BN hybrid, Napier as a male parent is responsible for providing perenniality and tillering habit whereas quality is contributed by female parent pearl millet. The grass has gained considerable importance in livestock rearers because of its quick growth, better tillering and rejuvenating capacity. Weed management in forages is very important for higher and quality forage production (Ghosh *et al.,* 2016). Palsaniya *et al.* (2015) reported that weed dynamics and management strategies are greatly influenced by crop type (annual or perennial), varietal nature (erect or spreading or drooping leaf habit) and spacing (closer or wider) regimes. During initial stages of BN hybrid, a variety of grassy and broad leaved weeds occupy the open space available because of wide row spacing of the crop. Weeds compete with BN hybrid for nutrients, space, light and water resources. Integration of chemical weed management with hand weeding as well as mechanical weeding has been reported as effective and economically viable method of weed management (Ram *et al*., 2005). Prabhu *et al*. (2015) also reported that integrated weed management in forage crops can be a better option to minimize the weed seed bank. The potential role of chemical component in integrated management is well known in many crops whereas; the information on selectivity of herbicides in Bajra Napier hybrid is scanty. Keeping this in view, the present study was under taken with the objective to find out the most suitable herbicide for weed management in BN hybrid under semi-arid climatic condition.

Materials and Methods

Experimental details: Field experiment was conducted during *kharif* 2013 and 2014 at Crop Production Farm, Indian Grassland and Fodder Research Institute, Jhansi. The soil of the experimental field was sandy clay loam in texture, acidic in reaction (pH of 6.6), low in available nitrogen (110.0 kg ha^{-1}) and phosphorus (17.02 kg ha^{-1}) and medium in potassium (197.12 kg ha^{-1}). Treatments were laid out in randomized block design with three replications. The plot size of the experiment was 5 m x 4 m. The treatments consisted of oxadiargyl 0.09 kg ha^{-1} (T_1), bispyribac sodium 25 g ha^{-1} (T_2), 2,4 D EE 1 kg ha^{-1} + atrazine 0.75 kg ha^{-1} (T_3), oxadiargyl 0.09 kg ha^{-1} followed by 2,4 D EE 1 kg ha^{-1} (T_4), fenoxaprop-p-ethyl 0.08 kg ha^{-1} + 2,4 D EE 1 kg ha^{-1} (T_5), pendimethalin 0.75 kg ha^{-1} (T_6), atrazine 0.75 kg ha^{-1} (T_7), atrazine 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1} (T_8), weed free check (T_9) and weedy check (T_{10}). The pre-emergence and post-emergence herbicides were sprayed on 3-5 days after planting and 20-25 days after planting, respectively with the help of knapsack sprayer fitted with flat fan nozzle and the weeding in weed free check was started after a week of planting and continued till 70 days after planting at 25 days interval. The land was ploughed once with a disc plough followed by a single pass of cultivator and a leveler to make the field without undulation. The even aged seedlings were planted at 1 m x 1 m row to row and plant to plant spacing immediately after the rainfall in order to achieve a better crop standing. The experimental plot was irrigated as and when needed. Uniform dose of N, P_2O_5 and K_2O was 60, 50, 40 kg ha^{-1}, respectively applied as basal dose to all the treatments and 30 kg ha^{-1} N was applied after each cut. Nitrogen in the form of urea was applied as split dose after each cut whereas, phosphorus and potash were applied as basal in the form of single super phosphate and muriate of potash. Total six cuts were taken, the first cut was at 60 DAP and the subsequent cuts were done at 35 days after the previous cut. A sample of 100g green fodder was collected to dry at 60^{0}C for 24 hrs to calculate the dry fodder yield, and the yield of Bajra Napier hybrid was estimated at each cut. The pooled values for two years were calculated. The observations on weed density and dry weight were recorded after 20 days after herbicides application using the quadrate (1 meter). From this data the total weed density and dry weight, weed control index, weed control efficiency and weed index were derived using the formulae of Misra and Misra (1997).

***Statistical analysis*:** Weed density and weed biomass values were subjected to square root transformation (“X + 1) before statistical analysis to normalize data distribution. The experimental data were analysed by using standard statistical procedure given by (Gomez and Gomez, 1984) for randomized block design. Analysis of variance (ANOVA) was performed using the JMP Pro 12 to test the effects of different herbicides treatment on weed density, dry weight and crop yield.

Results and Discussion

***Major weed flora*:** The experimental field was dominated by natural infestation of broad leaved weeds (BLW) like *Commelina benghalensis* (L.), *Digera arvensis* (Forsk.), *Catharanthus pusillus* (Murr.), *Leucas aspera* (Link.), *Cleome gynandra* (L.), *Cucumis melo* (L.), *Physalis minima* (L.), *Celosia argentea* (L.), *Cleome viscosa* (L.) and grasses like *Echinochloa crus-galli* (L.) Beauv, *Cynodon dactylon* (L.), *Digitaria sanguinalis* (L.) Scop. and sedges like *Cyperus rotundus* (L.). Among the weed flora averaged over two years and various treatments, the maximum relative percentage was of *Cyperus rotundus* (36%) followed by *Commelina benghalensis* (24%) and *Echinochloa crusgalli* (18%).

***Weed density and dry weight*:** Application of herbicides significantly influenced the weed density, dry weight and weed control efficiency. The maximum weed density was recorded in weedy check followed by fenoxaprop-p-ethyl 0.08 kg ha^{-1} mixed with 2, 4 D EE 1 kg ha^{-1} and oxadiargyl 0.09 kg ha^{-1} (Table 1). Significantly lower weed densities of 298 m^{-2} and 561 m^{-2} were recorded with application of oxadiargyl 0.09 kg ha^{-1} at 3-5 DAP followed by 2, 4 D EE 1 kg ha^{-1} at 20-25 DAP during 2013-14 and 2014-15 compared with other treatments and this was followed by atrazine 0.75 kg ha^{-1} mixed with pendimethalin 0.75 kg ha^{-1} at 3-5 DAP. Bhattacharya *et al*., (2005) reported that application of oxadiargyl 80% WP @ 100 g a.i. ha^{-1} showed better performance in controlling weed population throughout the growing period of rice crop due to prolonged persistence of herbicidal activity in soil. Despite of longer persistency in soil, oxadiargyl was not toxic to cattle because the mammalian toxicity of this herbicide is high (oral LD$_{50}$ rate>5000 mg/kg; Anonymous, 2002). Application of oxadiargyl 0.09 kg ha^{-1} at 3-5 DAP followed by 2, 4 D EE 1 kg ha^{-1} at 20-25 DAP and atrazine 0.75 kg ha^{-1} mixed with pendimethalin 0.75 kg ha^{-1} at 3-5 DAP reduced the weed density by 75% and 70%, respectively compared with the weedy check (Table 1). Maximum containment in weed biomass (Table 2) was recorded in 2013-14 (18 g m^{-2}) and 2014-15 (35 g m^{-2}) in oxadiargyl 0.09 kg ha^{-1} at 3-5 DAP followed by 2, 4 D EE 1 kg ha^{-1} at 20-25 DAP followed by a tank mixture of atrazine at 0.75 kg a.i. ha^{-1} with pendimethalin at 0.75 kg a.i. ha^{-1}. The phytotoxic effect of herbicide treated plots leads to reduction in weed density and dry biomass over weedy check. The results pertaining to weed density reduction were evenly reflected in the form of weed biomass suppression (Khaliq *et al*., 2014). Minimum weed density and biomass in oxadiargyl followed by 2, 4 D EE treated plots were presumably due to control of both grassy and broad leaved weeds especially at the early as well as middle of the crop growth stages. A narrow spectrum activity especially against grassy weeds rendered by other herbicides might have been less effective treatments in the experiment. The reduction in weed density and biomass under the influence of efficient oxadiargyl treatments was in line with the findings of Ramani and Khanpara (2010). Singh *et al*. (2016) also reported that sequential application of oxadiargyl PRE followed by bispyribac- sodium POST had 64-82% reduction in weed density.

Table 1. Effect of treatments on weed density (number m^{-2})

Treatment	Total weeds			*Commelina benghalensis* (L.)		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
T_1	30.00 (984)	32.03 (1082)	31.00 (1033)	14.00 (243)	16.00 (285)	15.00 (264)
T_2	27.48 (861)	32.15 (1068)	30.03 (964)	13.50 (189)	14.00 (197)	13.69 (193)
T_3	21.17 (482)	28.49 (812)	25.34 (647)	7.00 (47)	11.44 (132)	9.43 (89)
T_4	17.15 (298)	23.40 (561)	20.62 (430)	7.00 (49)	11.65 (148)	9.63 (99)
T_5	32.23 (1066)	39.66 (1590)	36.16 (1328)	13.37 (179)	16.01 (264)	14.77 (221)
T_6	23.57 (572)	25.00 (626)	24.34 (599)	11.37 (149)	13.03 (181)	12.27 (165)
T_7	29.05 (847)	27.06 (732)	28.09 (790)	19.12 (395)	17.49 (321)	18.33 (358)
T_8	20.45 (430)	24.06 (578)	22.43 (504)	8.00 (69)	11.55 (139)	10.04 (104)
T_9	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_{10}	40.00 (1616)	43.00 (1846)	41.47 (1731)	13.48 (181)	15.19 (235)	14.38 (208)
SEm ±	3.21	2.60	2.72	2.49	2.30	2.30
CD (P<0.05)	9.61	7.80	8.16	7.46	6.89	6.90

Treatment	*Echinocloa crusgalli* (L.) Beauv.			*Cyperus rotundus* (L.)		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
T_1	14.29 (320)	15.00 (320)	14.60 (320)	9.49 (111)	12.00 (137)	11.00 (124)
T_2	12.13 (182)	12.51 (182)	12.33 (182)	16.52 (319)	22.00 (483)	19.49 (401)
T_3	9.57 (121)	10.00 (127)	10.00 (124)	13.17 (225)	19.05 (388)	16.66 (307)
T_4	8.46 (72)	11.06 (129)	10.00 (100)	9.00 (111)	13.00 (163)	11.47 (137)
T_5	16.3 7(280)	16.01 (270)	16.19 (275)	21.53 (497)	28.40 (807)	25.36 (652)
T_6	8.59 (77)	8.16 (66)	8.42 (72)	16.02 (268)	17.16 (295)	16.66 (281)
T_7	11.75 (146)	10.47 (116)	11.15 (131)	12.00 (171)	12.23 (160)	12.16 (165)
T_8	8.58 (76)	7.14 (52)	8.00 (64)	14.60 (223)	17.23 (299)	16.01 (261)
T_9	1.00 (0.00)	1.00 (0.00)	1.00 (0.0)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_{10}	19.21 (394)	19.00 (379)	19.09 (387)	28.30 (807)	27.49 (764)	28.00 (785)
SEm ±	3.36	3.281	3.29	2.25	1.31	1.47
CD (P<0.05)	NS	NS	NS	6.75	3.94	4.41

Treatment	Other weeds		
	2013-14	2014-15	Mean
T_1	14.00 (310)	16.71 (339)	15.65 (324)
T_2	11.65 (169)	14.07 (204)	13.10 (187)
T_3	8.47 (88)	12.32 (164)	10.63 (126)
T_4	8.13 (65)	10.83 (120)	9.66 (93)
T_5	10.52 (109)	15.44 (248)	13.31 (179)
T_6	8.57 (76)	9.19 (83)	8.95 (80)
T_7	11.19 (135)	11.33 (134)	11.29 (134)
T_8	7.87 (61)	9.41 (88)	8.76 (75)
T_9	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
T_{10}	15.01 (233)	21.64 (467)	18.74 (350)
SEm ±	3.09	2.50	2.62
CD (P<0.05)	NS	7.50	7.86

Percent control of weeds over weedy check: The dominant weeds observed in Bajra Napier hybrid were *Commelina benghalensis* (L.), *Echinocloa crus-galli* (L.) Beauv and *Cyperus rotundus* (L.). Treatment oxadiargyl 0.09 kg ha^{-1} at 3-5 DAP followed by 2, 4 D EE 1 kg ha^{-1} at 20-25 DAP accounted lowest percentage of *Commelina benghalensis* (L.), *Echinocloa crus-galli* (L.) Beauv, and *Cyperus rotundus* (L.) at seedling stage in both the years of experiments. The application of oxadiargyl 0.09 kg ha^{-1} at 3-5 DAP followed by 2, 4 D EE 1 kg ha^{-1} at 20-25 DAP virtually killed both narrow and broad leaved weeds in Bajra Napier hybrid. The percentage reduction of *Commelina benghalensis* (L.) was 72 and 18%, and the corresponding value for *Echinocloa crus-galli* (L.) Beauv was. 71 and 50%, while for *Cyperus rotundus* (L.) it was 87 and 68% in 2013 and 2014, respectively.

Phytotoxicity: The toxic effects of herbicides on the Bajra Napier hybrid were observed by visual method (phytotoxic rating scale) and found that oxadiargyl, bispyribac sodium, 2, 4 D ethyl ester + atrazine, fenoxaprop-p-ethyl + 2, 4 D EE, pendimethalin, atrazine, atrazine + pendimethalin were toxic at early stage of plant growth and plants recovered gradually (Okafor, 1986). The phytotoxicity effects on the crop were recorded at 7, 14 and 21 days after the application of herbicides (Table 3). Crop injury from oxadiargyl, bispyribac sodium, 2, 4 D ethyl ester + atrazine, fenoxaprop-p-ethyl + 2, 4 D EE, pendimethalin, atrazine, atrazine + pendimethalin were characterized by an initial reduction of plant height and a

Table 2. Effect of treatments on dry weight of weeds (g m^{-2})

Treatment	Total weeds			*Commelina benghalensis* (L.)		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
T_1	7.60(64)	8.16(70)	7.89(67)	3.58(15)	4.01(17)	3.81(16)
T_2	6.81(52)	7.86(63)	7.38(58)	3.45(11)	3.53(12)	3.49(12)
T_3	5.26(29)	6.96(48)	6.21(38)	1.93(3)	2.96(8)	2.50(5)
T_4	4.35(18)	5.87(35)	5.20(26)	1.97(3)	3.02(9)	2.56(6)
T_5	7.90(63)	9.60(93)	8.79(78)	3.41(11)	4.04(16)	3.75(13)
T_6	5.76(33)	6.08(36)	5.93(35)	2.98(9)	3.35(11)	3.17(10)
T_7	7.26(52)	6.76(45)	7.02(48)	4.79(24)	4.39(19)	4.60(21)
T_8	5.02(25)	5.83(33)	5.47(29)	2.18(4)	3.00(8)	2.65(6)
T_9	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.00)	1.00(0.00)
T_{10}	9.75(95)	10.58(11)	10.18(103)	3.44(11)	3.84(14)	3.65(12)
SEm ±	0.85	0.71	0.74	0.57	0.54	0.53
CD (P<0.05)	2.55	2.13	2.22	1.72	1.62	1.61

Treatment	*Echinocloa crusgalli* (L.) Beauv.			*Cyperus rotundus* (L.)		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
T_1	3.97(22)	4.10(22)	4.04(22)	2.40(6)	2.80(7)	2.65(6)
T_2	3.38(13)	3.47(13)	3.43(13)	3.83(16)	4.97(24)	4.47(20)
T_3	2.75(8)	2.81(9)	2.78(9)	3.14(11)	4.38(19)	3.86(15)
T_4	2.44(5)	3.09(9)	2.81(7)	2.36(6)	3.01(8)	2.75(7)
T_5	4.44(20)	4.35(19)	4.39(19)	4.91(25)	6.42(40)	5.75(33)
T_6	2.47(5)	2.36(5)	2.43(5)	3.72(13)	3.96(15)	3.85(14)
T_7	3.26(10)	2.94(8)	3.11(9)	2.89(9)	2.91(8)	2.91(8)
T_8	2.47(5)	2.12(4)	2.31(4)	3.41(11)	3.97(15)	3.71(13)
T_9	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)	1.00(0.0)
T_{10}	5.18(28)	5.11(27)	5.15(27)	6.40(40)	6.22(38)	6.31(39)
SEm ±	0.85	0.83	0.83	0.47	0.28	0.31
CD (P<0.05)	NS	NS	NS	1.40	0.85	0.94

Treatment	Other weeds		
	2013-14	2014-15	Mean
T_1	3.90(22)	4.54(24)	4.28(23)
T_2	3.26(12)	3.85(14)	3.61(13)
T_3	2.47(6)	3.41(12)	2.99(9)
T_4	2.35(5)	3.03(8)	2.73(7)
T_5	2.94(8)	4.20(17)	3.65(13)
T_6	2.47(5)	2.61(6)	2.56(6)
T_7	3.12(9)	3.15(9)	3.15(9)
T_8	2.30(4)	2.67(6)	2.51(5)
T_9	1.00(0.0)	1.00(0.0)	1.00(0.0)
T_{10}	4.09(16)	5.80(33)	5.05(25)
SEm ±	0.78	0.63	0.66
CD (P<0.05)	NS	1.90	1.99

change in leaf colour. In the case of oxadiargyl, leaves became dark to light purple in colour at early stage whereas after seven days of application they recovered with very slight phytotoxic effect. Yadav *et al.* (2004) observed some phytotoxicity on cumin leaves which was recovered in later stages. Similarly, application of oxadiargyl at higher rates (0.40, 0.45 and 0.50 kg a.i. ha^{-1}) caused a slight scorching on the lower sides of potato leaves in the first three weeks after spraying (Barbe *et al.*, 2001).

Weed control efficiency, weed control index and weed index: The yield loss caused by weed infestation in comparison with weed free plots was described by using weed index (Suria *et al.*, 2011). It reflected the effectiveness of applied herbicide in securing yield loss against weed competition and a lower value of weed index means higher herbicide efficiency. Application of oxadiargyl 0.09 kg ha^{-1} at 3-5 DAP followed by 2, 4 D EE 1 kg ha^{-1} at 20-25 DAP recorded lowest weed index (Table 5) in 2013-14 (19.63) and 2014-15 (15.10) than rest of the herbicide treatments. Highest value of weed control efficiency (based on biomass of weeds) and weed control index (based on weed density) are required for effective weed management. Application of oxadiargyl 0.09 kg ha^{-1} + 2, 4 D EE 1 kg ha^{-1} also recorded highest WCE and WEI (Table 4) in 2013-14 (81 and 82%, respectively) and 2014-15 (69 and 69%, respectively). This was followed by atrazine 0.75 kg ha^{-1} + pendimethalin

0.75 kg ha^{-1} in 2013-14 (74 and 70%, respectively) and 2014-15 (74 and 68%, respectively).

Table 3. Effect of herbicides on weed control and crop toxicity rating

Herbicides	Crop toxicity rating**	Weed control rating*
Oxadiargyl 6 % EC	3	1
Pendimethalin 30 % EC	3	1
Atrazine 50 % WP	3	1
Bispyribac sodium 10 SC	4	1
2.4 D EE+ Atrazine	3	2
2.4 D EE	2	1
Fenoxaprop-p-ethyl + 2.4 D EE	4	5

*Rating[1] 3 indicates = moderate weed control, 4 = poor weed control, 2 = very good weed control; **Rating[2] 1 indicates = very slight crop injury 2 = slight injury, 5 = 100 % killing of crops

Table 4. Effect of herbicides treatment on weed control efficiency (%), weed control index and weed index in Bajra Napier hybrid

Treatment	Weed control efficiency		Weed control index		Weed index	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	37	39	43	43	20	16
T_2	49	45	51	43	28	22
T_3	67	55	69	55	43	31
T_4	81	69	82	69	20	15
T_5	33	16	34	13	23	18
T_6	64	67	64	65	38	28
T_7	44	59	47	60	26	20
T_8	74	70	74	68	51	37
T_9	100	100	100	100	00	00
T_{10}	00	00	00	00	69	49
CD (P=0.05)	34	28	30	24	31	21
SEm	11	9	10	8	10	7

***Green and dry fodder yield*:** Green fodder and dry matter yield of Bajra Napier hybrid was significantly influenced by herbicide treatments. Highest green fodder (66.13 t/ha and dry matter yield (13.31 t/ha) were recorded in weed free check followed by oxadiargyl 0.09 kg. ha^{-1} at 3-5 DAP followed by 2, 4 D EE 1 kg ha^{-1} at 20-25 DAP. Whereas, the lowest green forage and dry matter yield was recorded in weedy check (Table 5). Highest yield in oxadiargyl followed by 2, 4 D EE treatment was probably attributed to better control of weeds right from crop emergence up to critical period of crop-weed competition which enhanced the efficient utilization of growth resources like nutrients, moisture, and light by Bajra Napier hybrid and ultimately led to higher biological yield. The results were in confirmation with the findings of Ahmed and Chauhan (2014). However, obtained yield was comparatively lower than average yield of Bajra Napier hybrid, which was attributed to poor fertility of soil.

Table 5. Effect of treatments on green and dry fodder yield (t ha^{-1}) of Napier Bajra hybrid (pooled data of two years)

Treatment	Green fodder yield	Dry fodder yield
T_1	$64.96^{b\,c}$	$13.05^{b\,c}$
T_2	$60.66^{b\,c}$	$12.19^{b\,c}$
T_3	$58.00^{c\,d}$	$11.69^{c\,d}$
T_4	66.13^{b}	13.31^{b}
T_5	$64.66^{b\,c}$	$13.02^{b\,c}$
T_6	$57.66^{c\,d}$	$11.61^{c\,d}$
T_7	$61.66^{b\,c}$	$12.39^{b\,c}$
T_8	$52.66^{d\,e}$	$10.61^{d\,e}$
T_9	77.40^{a}	15.54^{a}
T_{10}	47.46^{e}	9.57^{e}
2013	81.83^{a}	16.26^{a}
2014	64.96^{b}	13.05^{b}
CD (P=0.05)	<0.001	<0.001

Means bearing different superscripts in a column differ significantly (P<0.001)

Conclusion

On the basis of the findings, it was concluded that higher Bajra Napier hybrid fodder yield per unit area can be achieved by keeping the field free from weed during the initial critical period of weed infestation. Maximum weed biomass reduction was observed with the sequential application of oxadiargyl 0.09 kg ha^{-1} followed by 2, 4 D EE 1 kg ha^{-1} which gave 36% higher fodder yield of Bajra Napier hybrid. Therefore, the sequential application of these herbicides could be a better option under semi-arid agro-climatic condition.

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