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Evaluation of propaquizafop: A new molecule as post emergence herbicide in potato

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Abstract
A field experiment was conducted during winter seasons of 2011-12 and 2012-13 to evaluate different doses of propaquizafop herbicide along with weed free and weedy check treatments in west - central region of India. The field was mainly infested with *Chenopodium murale, Chenopodium album, Celosia argentia*. Among monocot grasses *Echinochloa crusgallis* was prominent weed. Though there was variability in weed count under different herbicide doses but it was statistically on par with weedy check treatment which had highest weed density (91 m^{-2}), while weed free recorded lowest. Weeding + earthing (18 m^{-2}) treatment also recorded statistically lower number of weeds. Inefficient weed control by the molecule resulted in poor yield attributes and yield of potato. Total tuber number was highest with weeding + earthing treatment (355000 ha^{-1}) remaining statistically superior over various levels of propaquizafop and total tuber yield was also maximum in weed free plots (22.8 t ha^{-1}) which was markedly higher over propaquizafop doses. It is clear from WI that non control of weeds caused reduction in tuber yield ranging from 13 – 25 % in different herbicide treatments. Uptake of nitrogen was highest with weedy check (153 kg ha^{-1}) which was significantly higher over all other treatments. Highest Gross (₹183000 ha^{-1}), net return (₹103000 ha^{-1}) and B: C ratio (2.3) were recorded with weed free treatment. Relative production efficiency (30%) and water use efficiency (91 kg tuber ha^{-1}-mm) was also highest with weed free treatment. Weeding + earthing treatment produced 55% lower weed dry weight, 17.6% higher tuber yield and increased net returnby 94% over weedy check. Weed control by weeding + earthing increased water use efficiency by 18% compared to weedy check. Overall analysis of data suggests that post emergence application of herbicide propaquizafop was not effective in controlling weeds in potato.

Keywords: propaquizafop, post emergence herbicide, weed control, weed density, water use efficiency, net return, relative productivity efficiency.

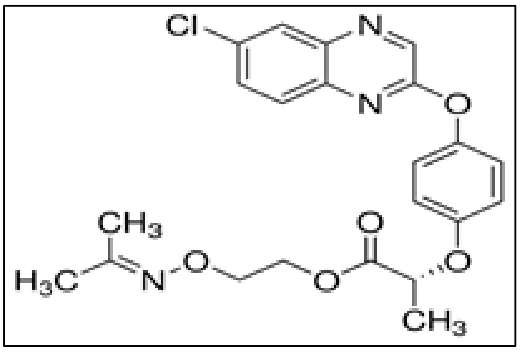
Introduction

Weeds cause enormous losses in crop productivity at global level. In India, yield losses in potato crop due to weed menace range from 10 to 80% (Lal and Grewal, 1991). The problem of weeds may vary with soil fertility levels as higher available nutrients in soil usually stimulate the germination and growth of weeds earlier than the growth of potato plants. Further potato requires higher doses of manures and fertilizer for realising its yield potential and if weeds are not controlled properly side by side of nutrient management than reduction in potato yield is very high. Proper weed management is necessary in potato crop to reduce inter-specific competition for space, nutrients, soil moisture, radiant energy and to obtain maximum fertilizer and water use efficiency (Rawal *et al*., 2014). In early phase of crop growth, emergence and growth of potato is slow, and wider row spacing along with frequent irrigation provide ample opportunity for weeds to grow luxuriantly. Shortage of farm labour makes it difficult to manage weeds at most critical stages of crop growth. Mechanization of potato planting and reduction in size of farm holding has vanished hoeing and earthing up operations now, which were usual practices earlier. Nitrogenous fertilizers are generally broadcasted once or twice during 20-50 days of crop giving rise to further weed menace. Chemical weed control is effective, faster and much less cumbersome as larger areas can be covered in a short span with less labour. Ample herbicide formulations like metribuzin, pendimethalin, alochlor etc are available before crop initiation. But there is lack of post emergence molecules in potato crop as if farmers are not able to apply pre emergence herbicide, then weeds start occurring in early stage and at that time, no proper alternate is available. Post emergence contact herbicide paraquat is stage sensitive (5% emergence) and hence is less effective for next flush of weeds.

Attempts are being made to find and evaluate available post emergence molecules at national level. In this series, propaquizafop was evaluated in different doses for estimating its weed control efficiency and its impact on potato productivity.

Materials and Methods

A field experiment was conducted consecutively for two crop seasons during winter seasons of 2011-13 at research farm (26º N latitude, 78º E longitude and 207 m above mean sea level) of Central Potato Research Station, Gwalior (MP). Soil was silty - clay loam having normal pH (8.05) & electrical conductivity (0.32dSm/m), low organic carbon (0.23%) & available nitrogen (125.4 kg ha^{-1}), medium available phosphorous (41.6 kg ha^{-1}) and high available potassium (470 kg ha^{-1}). The study comprised ten treatments viz., weedy check, weed free through hand weeding at 20 and 40 days after planting (d), hand weeding+ earthing up at 25d, post emergence application of propaquizafop at the rate of 50, 75, 100, 125, 150, 200 and 400% of its recommendations (650 ml ha^{-1}). Treatments were arranged in a randomized block design consisting three replications. Seed size tubers of variety Kufri Jyoti were planted on 15 November 2011 and 17 November 2012 at inter & intra row spacing of 60x20 cm. Crop was fertilized with 180: 34.9: 100 kg ha^{-1} of N, P and K, respectively. Half dose of N and full doses of P and K were applied at planting and remaining half doses of N was applied at 25 d at the time of inter-cultivation and earthing up (25 d). Propaquizafop under study belongs to the group aryloxyphenoxypropionates (FOPs) and is a white powder insoluble in water. It is a post-emergence herbicide for selectively controlling a wide range of annual and perennial grasses in sugar beets, canola, soybean, sunflower, vegetables, orchards, vineyards and forest. Its mode of action is inhibition of enzyme acetyl-CoA carboxylase.



Structural Formula of Propaquizafop

Propaquizafop was applied as per the treatments on 09 December 2011 and 10 December 2012 during first and second years at 3-4 leaf stage of weeds by sprayer. Five irrigations (each time 50mm) were applied and the crop also received 18 and 64 mm winter rains during 2011-12 and 2012-13, respectively. The quantification of irrigation water applied was measured using depth –interval method. Manual weeding was done in weed free and hand weeding+ earthing up treatments. All the standard cultural and plant protection practices were followed as per recommended schedules to raise a stress free crop. Haulms cutting was done at 90 days after planting and harvesting was carried out ten days later after curing of tuber's skin. All observations related to emergence, growth and productivity were recorded as per the schedule during crop season. Tuber harvesting and grading was done manually, and tubers of <25 g, 25 – 75 g and >75 g were considered as small, medium and large, respectively. Data on weed density and biomass were recorded at harvest. Weeds were counted species wise and were removed for recording their biomass. Weed samples were sun dried and later on oven dried at 70ºC until constant weight was attained. The standard analytical method was used for determination of nutrient N by alkaline permanganate method. Nutrients N, P and K content and uptake by potato and weeds were analyzed through standard laboratory procedure. Economics was computed using prevailing market prices for inputs and outputs such as tuber (₹ 8 kg), manual labour (₹ 200/day), and weedicide as per treatment. Relative production efficiency (RPE) and relative economic efficiency (REE) were calculated by using following formula (Urkurkar *et al*., 2006)

$$\text{Relative production efficiency (RPE)} = \frac{\text{Production in treated plot-production in weedy check}}{\text{Production in weedy check}} \times 100$$

$$\text{Relative economic efficiency (REE)} = \frac{\text{Net Return of treated plot- Net Return of weedy check}}{\text{Net return of weedy check}} \times 100$$

Water use efficiency (WUE) was also worked out using following formula (Reddy and Reddy, 2002). Weed index (%), weed control efficiency (%) and weed control index were worked out using formula proposed by Gill and Vijayakumar (1969), Mani *et al*. (1973) and Misra and Tosh (1979), respectively.

$$\text{WUE} = \frac{\text{Tuber yield (kg/ha)}}{\text{Water applied through irrigation (mm)}}$$

$$\text{Weed control efficiency (WCE)} = \frac{\text{Weed population in control - Weed population in treated plot}}{\text{Weed population in control}} \times 100$$

$$\text{Weed control index (WCI)} = \frac{\text{Weed dry weight in control-Weed dry weight in treated plot}}{\text{Weed dry weight in control}} \times 100$$

$$\text{Weed index (WI)} = \frac{\text{Tuber yield in weed free - tuber yield in treated}}{\text{Tuber yield in weed free}} \times 100$$

Results and Discussion

Effect of weeds: The field was infested with weeds in its intensity order of *Chenopodium murale* (Kharbathua), *Chenoporium album* (Bathua), *Celosia argentia* (Safed). Among monocot grasses *Echinochloa crusgallis* (Sanwa) was prominent weed. In general, application of propaquizafop herbicide could not reduce number of weed count significantly. Highest weed density (91 m^{-2}) was recorded with weedy check which was significantly higher over weed free and hand weeding + earthing treatments. Though there was variability in weed count under different herbicide doses but it was statistically on par with weedy check treatment. Highest weed fresh weight (1121 g m^2) was recorded with weedy check treatment which was significantly higher than weed free and hand weeding + earthing treatment. Though lower fresh weight of weeds was recorded in different herbicide treatments but it was statistically on par with weedy check treatments.Weed dry weight showed some different trend though it was highest with weedy check (260 g m^{-2}) which was significantly higher than weed free and weeding + earthing.

Weed control indices: Highest weed control efficiency (WCE) was recorded with weed free (91%) followed by weedimg + earthing (80%). These were significantly higher than all other treatments. Lowest weed control efficiency was recorded with weedy check which was statistically on par with herbicide treatments. This might be due to non-effectiveness of herbicide in controlling potato weeds. Weed control index was also highest with weed free treatment (90%) followed by weeding + earthing (77%). Lowest WCI was recorded with weedy check which was statistically on par with other herbicide treatments. Weed index was lowest with weed free followed by weeding + earthing (9%). It is clear from WI that non control of weeds caused reduction in tuber yield ranging from 13 – 25 % in different herbicide treatments.

Growth attributes: Tuber emergence was very good in all the treatments. In general it was higher in weed infested treatments compared to weed controlled treatments. This might be due to increased competition between crop and weeds. There was decrease in number of stems/plant in weedy check (2.1) and other weed infested plots. Highest stem/plant was recorded with weed free (2.8) treatment which was significantly higher over all other treatments. Highest number of compound leaves were recorded with weed free treatments (45) which was significantly higher over all other treatments except weeding + earthing up treatment. Reduction in number of compound leaves might be due to competition for light, nutrient and water from weeds (Boydston, 2010).

Number and yield of tubers: In general weed free plots produced comparatively higher number of small size tubers compared to weed infested treatments. Highest small size tubers (240 thousand ha^{-1}) were produced with weed free treatment which was significantly higher over all other treatments. Highest medium size tubers (153 thousand ha^{-1}) were produced with weeding + earthing treatment which was significantly higher over propaquizafop (200%) but statistically on par with all others treatments. There was no any significant variation in number of over - size tubers due to different treatments. Total tuber number (355 thousand ha^{-1}) was highest with weeding + earthing treatment which was significantly higher over propaquizafop treatments of 75, 125, 150 and 200%, but statistically on par with other treatment. Highest small size tuber yield (2.4 t ha^{-1}) was recorded with weed free which was significantly higher over weedy check and propaquizafop doses of 50, 125, and 400%. Yield of medium size tubers (9.3 t ha^{-1}) was highest with weeding + earthing which was significantly higher than weedy check, propaquizafop level of 50, 125, 150, and 200%. Large size tuber yield (11.8 t ha^{-1}) was highest with weed free though it was statistically on par with other treatments. Total tuber yield (22.8 t ha^{-1}) was highest with weed free which was significantly higher than weedy check, propaquizafop doses of 50, 100, 125, 150, 200 and 400%. Once germinated and established, weeds quickly begin to complete with potato plants. Weed – potato competition ultimately determines the yield loss of potato as well as total weed biomass. Competition with weeds also affect tuber size and finally yield loss (Wall and Friesen, 1990 a).

Nutrient uptake: Nitrogen uptake increased with increasing weeds. Nitrogen uptake by weeds was recorded to the tune of 43 kg ha^{-1} with weedy check. Uptake of nitrogen was highest with weedy check which was significantly higher over weed free and weeding + earthing treatment. It was interesting to note that nitrogen removal from weedy check plots was higher than that of weed control plots. It might be due to higher efficiency of weeds in N uptake as compared to potato having sparse root system (Sud *et al*., 1999). Higher P uptake by weeds was recorded with weedy check (6.5 kg ha^{-1}) which was significantly higher compared to other treatments. Highest K uptake by weeds was recorded with weedy check which was comparable to herbicide treatments. Uptake of K in weedy check (32 kg ha^{-1}) was significantly higher over weed free and weeding + earthing treatment. Nitrogen uptake by potato was highest with weed free treatment (83 kg ha^{-1}) which was significantly higher than Propaquizafop 200 and 400 % of RDF doses. P uptake by potato was statistically on par in weed free, weeding + earthing and weedy check. Highest K uptake by potato was recorded with weed free (88 kg ha^{-1}) which was significantly higher over all other treatment except weeding + earthing. Total uptake of nitrogen (potato + weeds) was highest with weedy check (121 kg ha^{-1}) which was significantly higher over weed free, weedy check and propaquizafop 200% treatments. Total P uptake (potato +

weeds) was highest with weed free (14.8 kgha^{-1}), which was significantly higher over almost all other treatments. There was no any significant effect of different treatments on total K uptake by potato + weeds.

Economics: Cost of cultivation varied as per treatment. Highest cost of cultivation was with weed free (₹ 80 thousand ha^{-1}) treatment due to involvement of higher cost of labour charges. This was followed by propaquizafop (400%). Highest Gross return (₹ 183 thousand ha^{-1}), net return (₹ 103 thousand ha^{-1}) and B: C ratio (2.3) were recorded with weed free treatment. This treatment was followed by weeding + earthing. Higher net return was on account of higher production of potato tubers in these treatments. Increased higher net return might be on account of better canopy and plant growth due to proper availability of sun light, moisture and nutrients resulting in higher yield and thereby net return (Singh *et al.*, 2011)

Production and economic efficiencies: Relative production efficiency was highest with weed free (30%) followed by weeding + earthing treatment (18%). The increased efficiency might be due to better utilization of native and applied resources under stress free environment. Relative economic efficiency (66) also showed similar trend. Water use efficiency was also highest with weed free treatment (91 kg tuber/ha mm) which was followed by weeding + earthing up treatment (83 kg tuber/ha - mm) Fig 1. Higher water use efficiency was attributed due to lesser competition with weeds which ultimately resulted in higher yield from applied irrigation water (Singh and Lal 2013).

Table 1: Effect of weed control treatments on growth attributes and weed parameters in potato (two years mean data).

Treatment	Growth attributes				Weed attributes			RPE (%)	REE (%)	Weed control indices		
	Tuber emergence/ 20 hill	Plant height (cm)	Stem/ plant	Leaves/ plant	Weed density (no./sq m)	Weed fresh weight (g/sq m)	Weed dry weight (g/sq m)			WCE (%)	WCI (%)	WI (%)
Weed free	19.4	24	2.8	45	8 (3.1)	137 (11.8)	27 (5.3)	30	66	91	90	0
Weeding + earthing	19.6	26	2.6	44	18 (4.3)	312 (17.7)	61 (7.6)	18	45	80	77	9
Weedy check	19.4	28	2.1	30	91 (9.6)	1121 (33.5)	260 (17)	0	0	0	0	23
Propaquizafop 50% RD	19.6	29	1.9	31	65 (8.1)	1120 (33.4)	250 (16)	(-) 3	(-) 3	29	4	25
Propaquizafop 75% RD	19.6	29	2.1	33	51 (7.1)	818 (28.6)	221 (14.8)	13	32	44	15	13
Propaquizafop 100 %RD	19.4	31	2.7	39	74 (8.6)	788 (28.1)	202 (14.2)	7	21	19	22	17
Propaquizafop 125% RD	19.4	28	2.2	35	74 (8.7)	882 (29.7)	206 (14.3)	(-) 1	2	19	21	24
Propaquizafop 150% RD	19.6	31	2.0	32	75 (8.7)	778 (27.9)	248 (15.7)	3	8	18	5	21
Propaquizafop 200% RD	18.8	28	2.2	37	62 (7.9)	911 (30.2)	227 (15.1)	(-) 7	(-) 15	32	13	29
Propaquizafop400% RD	19.2	29	2.1	37	70 (8.3)	945 (30.7)	237 (15.3)	3	6	23	9	20
SEm$\pm$	0.13	2.7	0.01	2.7	1.3	4.6	1.7	-	-	10	11	3
CD (P=0.05)	0.39	8.0	0.03	8.0	3.9	13.7	5.1	-	-	30	33	9

RPE = Relative production efficiency, REE = Relative economic efficiency, WCE = weed control efficiency, WCI = weed control index, WI = weed index, data given in bracket were transformed to sq root ($\sqrt{x+1}$) before statistical analysis

Table 2: Effect of weed control treatments on growth attributes yield and economics of on potato (two years mean data).

Treatment	Nuumber of tubers ('000/ha)				Yield of tubers (t/ha)				Economic parameters			
	Small	Medium	Large	Total	Small	Medium	Large	Total	Cost of cultivation (□'000/ha)	Gross return (□'000/h)	Net return (□'000/h)	B : C ratio
Weed free	240	119	69	307	2.4	8.6	11.8	22.8	80	183	103	2.3
Weedi g + earthing	135	153	67	355	1.8	9.3	9.6	20.7	74	164	90	2.2
Weedy check	120	116	71	309	1.7	7.1	8.8	17.6	79	141	62	1.8
Propaquizafop 50% RD	128	135	62	324	1.7	6.6	8.7	17.0	75	135	60	1.8
Propaquizafop 75% RD	109	125	56	290	1.9	8.0	9.9	19.8	75	157	82	2.1
Propaquizafop 100 %RD	140	118	69	327	2.0	7.5	9.4	18.9	76	151	75	2.0
Propaquizafop 125% RD	108	119	60	286	1.6	7.1	8.7	17.4	76	139	63	1.8
Propaquizafop 150% RD	107	115	66	288	2.0	6.7	9.4	18.1	77	144	67	1.9
Propaquizafop 200% RD	118	106	61	285	2.0	6.2	8.1	16.3	77	130	53	1.7
Propaquizafop 400% RD	121	131	50	302	1.7	7.8	8.7	18.2	79	145	66	1.8
SEm$\pm$	13	13	13	19	0.6	0.7	2.7	1.7	-	-	-	-
CD (P=0.05)	39	39	NS	58	1.8	2.1	NS	5.1	--	-	-	-

Table 3: Effect of weed control on nutrient uptake by weeds and potato (two years mean data).

Treatment	Nutrient uptake by potato (kg/ha)			Nutrient uptake by weeds (kg/ha)			Total nutrient uptake (kg/ha)		
	N	P	K	N	P	K	N	P	K
Weed free	83	8.3	88	5	0.5	3.0	88	8.8	91
Weeding + earthing	83	6.4	83	12	0.9	7.0	95	7.3	90
Weedy check	78	8.3	50	43	6.5	32.0	121	14.8	82
Propaquizafop 50% RD	74	3.8	60	33	3.8	31.0	107	7.6	91
Propaquizafop 75% RD	74	6.8	56	34	4.5	30.0	108	11.3	86
Propaquizafop 100 %RD	73	9.5	50	34	4.6	29.0	107	14.1	79
Propaquizafop 125% RD	73	8.2	68	39	3.9	28.0	112	12.1	96
Propaquizafop 150% RD	77	6.7	66	36	4.0	23.0	113	10.7	89
Propaquizafop 200% RD	56	4.0	58	35	3.7	26.0	91	7.7	84
Propaquizafop 400% RD	69	5.6	55	38	3.8	29.0	107	9.4	84
SEm$\pm$	3.7	0.7	5.4	3.6	0.5	3.3	5.3	0.8	6.0
CD (P=0.05)	10.9	2.1	16.0	10.7	1.6	9.8	15.7	2.4	NS

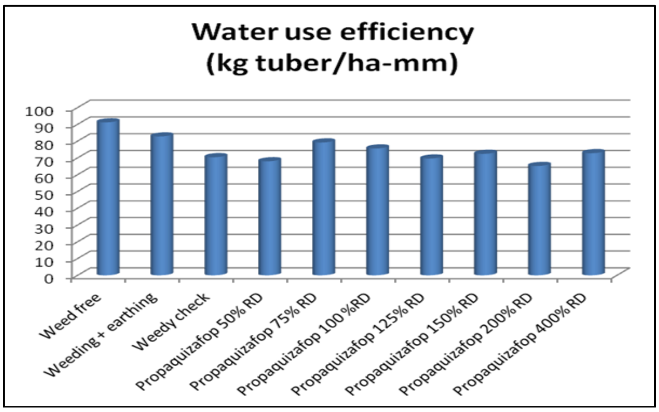


Fig 1: Water use efficiency of potato as influenced by weed control treatments

Conclusions

It can be concluded from the present study that weedicide propaquizafop tested with its different doses was ineffective in controlling weeds in potato.

Acknowledgement

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