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Response of various chemicals, neem cake and hand pulling on growth and development of Egyptian broomrape (*Phelipanche aegyptiaca*) in Indian mustard

R. SHARMA, [1]AMARJEET AND S. S. PUNIA

Department of Agronomy, CCS Haryana Agricultural University, Hisar- 125004, Haryana
[1]Regional Research Station, Bawal, Rewari- 123501, Haryana

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ABSTRACT

A field experiment was conducted to study the effect of glyphosate, neem cake, pendimethalin, metalaxyl and fertilizer dose combinations on growth and development of Egyptian broomrape (Phelipanche aegyptiaca) in Indian mustard. All the treatments involving glyphosate spray increased the plant height and siliquae plant^{-1}, 1,000 -seed weight, oil content and seed yield of mustard as compared to control. Application of 100 or 125% of recommended dose of fertilizer (N and P) + foliar sprays of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively reduced the infestation and fresh weight (g m^{-2}) of P. aegyptiaca significantly throughout the growing season and proved best in increasing yield as well as oil content in Indian mustard. Use of neem cake, pendimethalin and metalaxyl either alone or in combination with glyphosate exhibited control of P. aegyptiaca at early growth stages only.

Keywords **:** Glyphosate, hand pulling, Indian mustard, *neem* cake, pendimethalin and *Phelipanche aegyptiaca*

Broomrapes are the annual parasitic weeds that lack chlorophyll and can only reproduce through seeds (Saghir *et al*., 1973). Till 2009, *Orobanche* was the single genus known for all the broomrape species. Based on new nomenclature of broomrapes, *Orobanche aegyptiaca* and *Orobanche ramosa* are now known as *Phelipanche aegyptiaca* and *Phelipanche ramosa* (Joel, 2009). Broomrape attaches with the host plant with the help of haustoria, which connect the host vascular system and parasitic weed (Mabrouk *et al.,* 2010; Gevezova *et al.,* 2012), strongly competing with the host plant for water and assimilates. This causes moisture and assimilates starvation, host plant stress and growth inhibition, leading to extensive losses in crop yield and quality. Several vegetable and field crops are known to be affected due to broomrapes (Joel *et al*., 2007; Parker, 2009). In India, broomrapes have been reported as a main parasite of tobacco, tomato, brinjal, rapeseed mustard, cotton, jute, *etc*. *P. aegyptiaca* (Egyptian broomrape) has emerged as a major threat to rapeseed-mustard production in northwestern and central India including Rajasthan, Haryana, Punjab, Gujarat and Madhya Pradesh states. *P. aegyptiaca* in Indian mustard can be controlled using glyphosate (Sheoran *et al*., 2014; Punia, 2015) but its application at higher dose or wrong stage may cause toxicity to mustard. Thus, the scientific management of *P. aegyptiaca* in Indian mustard is necessary to improve productivity of the crop. Keeping these points in view, the present investigation was carried out to find the best practice to control *P. aegyptiaca* along with better growth and yield of Indian mustard.

MATERIALS AND METHODS

The experiment consisted of 11 treatments *viz.*, T_1- *Neem* cake 400 kg ha^{-1} before sowing, T_2- *Neem* cake 400 kg ha^{-1} before sowing followed by foliar spray of glyphosate at 20 and 40 g ha^{-1} + 1.0% $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively, T_3- *Neem* cake 400 kg ha^{-1} before sowing followed by foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively, T_4- *Neem* cake 400 kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25 DAS, T_5- *Neem* cake 400 kg ha^{-1} followed by pendimethalin as pre plant incorporation (PPI) at 0.75 kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25 DAS, T_6- *Neem* cake 400 kg ha^{-1} before sowing followed by soil application of metalaxyl 0.2 % at 25 DAS followed by foliar sprays of glyphosate at 40 g ha^{-1} at 45 DAS, T_7- Foliar sprays of glyphosate at 25 and 50 g ha^{-1} + 1.0% $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively, T_8- Foliar sprays of glyphosate at 25 and 50 g ha^{-1} at 25 and 55 DAS, respectively, T_9- 125% of recommended fertilizers (N and P) followed by foliar sprays of glyphosate at 25 and 50 g ha^{-1} + 1.0% $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively, T_{10}- Hand pulling of *P. aegyptiaca* shoots at 45, 65 and 85 DAS and T_{11}- Weedy check was conducted at CCS Haryana Agricultural University Regional Research Station, Bawal (Rewari) during *Rabi* season of 2014-15 to study the effect of different treatments on *P. aegyptiaca* and growth and yield of Indian mustard. Soil of the experimental field was sandy, low in organic carbon (0.3%) and nitrogen (143.4 kg ha^{-1}), medium in available phosphorus (17 kg ha^{-1}) and potassium (172 kg ha^{-1}) and neutral in pH (8.0). Total

Email : *ramansharmakaushik@gmail.com*

rainfall received during the growing season was 280.3 mm with maximum during 9th standard meteorological week (26th February-4th March) amounting 115.5 mm. The experimental field was naturally infested with *P. aegyptiaca* seed bank. After pre-sowing irrigation when the field was ready for seed bed preparation, the field was ploughed up twice with tractor drawn disc-harrow and once with cultivator followed by planking to get well pulverized seed bed for sowing. Each plot of experiment was 4.5 m long and 4 m wide.

The seed of variety RH 0749 of Indian mustard was sown on 25th October 2014 @ 5 kg ha^{-1} by *pora* method with the help of hand drawn plough keeping 45 cm inter-row and 15 cm intra-row spacing. The treatments were laid out in randomized block design with three replications. A standard formulation of glyphosate (41% SL) at various concentrations was used alone or in combination with ammonium sulphate (1% solution), *neem* cake, pendimethalin (30% EC), metalaxyl (72% WP) and fertilizer doses along with hand pulling and weedy check. *Neem* cake (400 kg ha^{-1}) was broadcasted and incorporated in soil before sowing seeds in first six treatments. The soil characteristics of experimental field and *neem* cake are shown in the table 1. Pendimethalin and metalaxyl were applied PPI @ 0.75 kg *a.i.* ha^{-1} and 0.2% at 25 DAS, respectively. *Phelipanche* shoots were hand pulled at 65 and 85 DAS, respectively. The recommended doses of nitrogen (80 kg N ha^{-1}) and phosphorus (30 kg P_2O_5 ha^{-1}) were applied in all the treatments except T_9, in which 125% of the recommended doses of nitrogen and phosphorus were applied.

Data on shoot number and fresh weight of *P. aegyptiaca* were obtained using quadrate method (Misra and Puri, 1954) at 60, 90, 120 DAS and at harvest. Mustard plant height was recorded at 40, 65, 95, 130 DAS and at harvest. Number of siliquae per plant was recorded from five tagged plants at harvest and average was calculated for one plant. Seeds per siliqua, 1,000 - seed weight, seed yield, harvest index and oil content (%) of Indian mustard were recorded after harvest by standard methods. The phyto-toxicity (0-100 scale) on mustard was recorded at 65 DAS by visually observing each plot and recorded in per cent. Data were analysed statistically using ANOVA and means were compared at 5% level of significance.

RESULTS AND DISCUSSION

No *P. aegyptiaca* shoot emerged out of soil irrespective of any treatment upto 40 DAS. Therefore, observation regarding number of number of *P. aegyptiaca* shoots m^{-2} was nil and no hand pulling was required at 45 DAS.

Broomrape studies

Significant difference was observed in number (Table 2) and fresh weight (Table 3) of *P. aegyptiaca* shoots m^{-2} at 60, 90, 120 DAS and at harvest of crop. Among all the treatments, different doses of glyphosate alone or in combination with fertilizers or *neem* cake gave maximum reduction in number and fresh weight of *P. aegyptiaca* shoots m^{-2}. The plots supplied with 125% of recommended fertilizers (N and P) followed by foliar sprays of glyphosate at 25 and 50 g ha^{-1} + 1.0% $(NH_4)_2SO_4$ at 25 DAS and 55 DAS, respectively (T_9) recorded significantly least *P. aegyptiaca* population per metre square (0.3) upto harvest (provided complete control upto 90 DAS) which was statistically at par with T_7 (1.3) and T_8 (2.3). All the treatments except *neem* cake @ 400 kg ha^{-1} recorded significantly lesser *P. aegyptiaca* shoots than control (weedy check) upto 90 DAS.

The effective treatments in reducing *P. aegyptiaca* population and fresh weight upto 60 DAS were T_3, T_7, T_8 and T_9 with no *P. aegyptiaca* emergence followed by T_2. It might be due to application of higher doses of glyphosate (25 g *a.i*. ha^{-1}) at 25 DAS in the respective treatments as compared to T_2 in which less dose of glyphosate led to emergence of *P. aegyptiaca* shoots thereby increasing their fresh weight too. Minimum *P. aegyptiaca* shoot number and fresh weight at 90, 120 DAS and at harvest were observed in T_9 strictly followed by T_7 and T_8 which might be because of effective control of *P. aegyptiaca* by glyphosate. Further reduction in the parasitic weed's population and fresh weight from 120 DAS to harvest might be due to the heavy rainfall in 9th SMW of 2015 lessening its fresh weight also. The reduction in *P. aegyptiaca* population with water availability has also been reported by Manschadi *et al.* (2001) in faba bean and Punia (2014) in mustard. The increase in number and fresh weight of *P. aegyptiaca* shoots after 60 DAS of mustard in T_3, T_2 and T_6 might be due to effect of early, less or single dose of glyphosate which did not prolong for longer time *i.e.* upto harvest. Similar findings were observed in mustard by Punia *et al.* (2010) and Sheoran *et al.* (2014). The decrease in number and fresh weight of *P. aegyptiaca* shoots in treatment T_7 over T_8 might be due to the addition of 1.0% $(NH_4)_2SO_4$ which might have resulted in increasing the efficacy of glyphosate against *P. aegyptiaca*. Turner and Loader (1980) and Harker (1995) have also reported an increase in efficacy or phyto-toxicity of glyphosate by the addition of $(NH_4)_2SO_4$. Minimum number and fresh weight of *P. aegyptiaca* shoots were recorded in T_9 which might be because of the combined effect of two doses of glyphosate, addition of 1.0% $(NH_4)_2SO_4$ and 25 percent extra nitrogen and phosphorus. Increasing

Table 1 : Various characteristics of soil of experimental field and *neem* cake

Parameter	N*	P_2O_5*	K_2O*	Organic carbon (%)	EC (dSm^{-1})	pH
Soil	143.4	17	172	0.30	0.20	8.0
Neem cake	1.15	0.13	1.78	-	-	-

** N, P_2O_5 and K_2O in soil and neem cake are presented in kg ha^{-1} and per cent, respectively*

Table 2 : Number of *P. aegyptiaca* shoots as influenced by different treatments

Treatment	Number of *P. aegyptiaca* shoots (m^{-2})			Harvest
	60 DAS	90 DAS	120 DAS	
T_1	3.4 (10.3)	5.5 (29.0)	8.3 (67.7)	5.5 (30.0)
T_2	1.6 (1.7)	3.1 (9.0)	5.4 (29.3)	3.8 (14.3)
T_3	1.0 (0)	2.4 (5.0)	4.3 (18.3)	2.9 (8.3)
T_4	3.2 (9.7)	5.0 (24.0)	7.7 (59.7)	5.5 (29.3)
T_5	2.7 (6.7)	4.8 (22.0)	7.7 (58.3)	5.3 (27.7)
T_6	2.3 (4.3)	4.2 (16.7)	7.1 (50.0)	5.0 (24.3)
T_7	1.0 (0)	1.6 (1.7)	2.2 (4.0)	1.5 (1.3)
T_8	1.0 (0)	1.7 (2.0)	2.5 (5.3)	1.7 (2.3)
T_9	1.0 (0)	1.0 (0)	1.2 (0.7)	1.1 (0.3)
T_{10}	2.9 (7.3)	2.3 (4.3)	8.3 (68.3)	5.7 (31.7)
T_{11}	3.8 (13.7)	6.1 (36.3)	8.8 (77.0)	6.2 (37.0)
LSD (0.05)	**0.6**	**0.9**	**1.5**	**1.1**

Notes : Original data were subjected to square root transformation $\sqrt{(X+1)}$ and presented in parentheses. The value of LSD was compared with the values outside the parentheses.

Table 3: Fresh weight of *P. aegyptiaca* shoots as influenced by different treatments

Treatments	Fresh weight of *P. aegyptiaca* (g m^{-2})			
	60 DAS	90 DAS	120 DAS	Harvest
T_1	8.0 (62.8)	13.0 (169.2)	16.2 (264.8)	6.7 (44.5)
T_2	2.5 (6.3)	6.5 (41.9)	10.0 (102.9)	4.4 (19.4)
T_3	1.0 (0)	4.7 (24.3)	8.2 (69.2)	3.6 (12.8)
T_4	7.4 (55.8)	11.5 (132.6)	15.4 (238.8)	6.7 (43.7)
T_5	6.3 (38.5)	10.9 (119.7)	14.9 (225.7)	6.4 (40.7)
T_6	4.6 (20.8)	9.0 (90.7)	13.7 (189.5)	6.2 (37.5)
T_7	1.0 (0)	2.7 (7.5)	4.1 (16.1)	1.7 (2.0)
T_8	1.0 (0)	2.8 (8.5)	4.7 (22.4)	1.9 (3.3)
T_9	1.0 (0)	1.0 (0)	1.7 (3.0)	1.2 (0.5)
T_{10}	6.3 (39.2)	5.4 (29.1)	16.3 (267.6)	6.8 (45.6)
T_{11}	9.0 (79.3)	15.5 (239.8)	17.1 (293.3)	7.1 (49.5)
LSD (0.05)	**1.3**	**2.1**	**3.0**	**1.3**

Notes : Original data were subjected to square root transformation $\sqrt{(X+1)}$ and presented in parentheses. The value of LSD was compared with the values outside the parentheses.

Table 4: Plant height of Indian mustard as influenced by different treatments

Treatments	Plant height (cm)			
	65 DAS	95 DAS	130 DAS	Harvest
T_1	69.3	175.2	202.6	203.4
T_2	74.8	185.0	217.4	219.0
T_3	75.8	187.8	219.9	221.7
T_4	71.2	176.9	204.6	205.8
T_5	71.4	177.9	206.1	207.1
T_6	73.6	181.4	211.6	212.7
T_7	77.2	189.8	222.9	224.6
T_8	76.7	188.7	221.5	223.4
T_9	81.5	196.8	231.5	232.7
T_{10}	70.3	174.8	202.3	203.2
T_{11}	66.8	169.0	197.2	198.1
LSD (0.05)	**6.4**	**9.6**	**11.7**	**11.1**

Table 5 : Number of siliquae plant^{-1}, seeds siliqua^{-1}, 1,000 -seed weight, seed yield, harvest index and oil content of Indian mustard and visual phyto-toxicity on Indian mustard as influenced by different treatments

Treatments	Number of siliquae plant^{-1}	Seeds siliqua^{-1}	1,000 -seed weight (g)	Seed yield (kg ha^{-1})	Harvest Index (%)	Oil content (%)	Visual phyto-toxicity (%) at 65 DAS
T_1	208	12.8	4.54	1537	21.0	37.7	1.0 (0)
T_2	264	13.5	4.88	2147	22.6	38.4	3.8(13.3)
T_3	271	13.7	4.99	2238	22.8	38.4	4.2 (16.7)
T_4	211	12.9	4.55	1567	21.2	37.8	1.0 (0)
T_5	225	13.0	4.61	1694	21.5	38.1	1.0 (0)
T_6	235	13.4	4.69	1782	21.7	38.2	1.0 (0)
T_7	284	13.9	5.18	2426	23.1	38.6	1.0 (0)
T_8	278	13.8	5.07	2308	22.9	38.5	1.0 (0)
T_9	306	14.1	5.42	2648	23.7	38.7	1.0 (0)
T_{10}	205	12.7	4.52	1519	20.9	37.8	1.0 (0)
T_{11}	192	12.3	4.35	1403	20.3	37.6	1.0 (0)
LSD (0.05)	26	0.8	0.27	225	0.7	0.3	0.4

Notes : Original data were subjected to square root transformation $\sqrt{(X+1)}$ *and presented in parentheses. The value of LSD was compared with the values outside the parentheses.*

the application of nitrogen in mustard decreased the population and fresh weight of *P. aegyptiaca* in T_9 over T_8 probably because of detrimental effect of the nitrogenous fertilizers on the parasitic infestation. Low rates of ammonium sulphate reduced broomrape infestation without any adverse effect on faba bean (van Hezewijk *et al*., 1991). Jain and Foy (1992) also observed that parasitism occurred most readily in potting media low in fertility. Addition of nitrogenous compounds to potting media resulted in inhibition of broomrape parasitism. Notably, Westwood and Foy (1999) also found that nitrogen inhibited the germination of broomrape seeds.

Maximum shoot number and fresh weight of *P. aegyptiaca* were found in weedy check followed by *neem* cake 400 kg ha^{-1} before sowing (T_1). Metalaxyl, *neem* cake and pendimethalin did not cause any reduction in number as well as fresh weight of *P. aegyptiaca* shoots at any stage of crop growth. Parker and Riches (1993) concluded that although many reports were published about the effect of herbicides belonging to dinitroanilines *i.e.* pendimethalin, trifluralin, dinitralin *etc*., but not even a single herbicide was efficient in controlling *P. aegyptiaca* in field conditions. Kumar (2002) also conducted preliminary studies for the control of broomrape in mustard and noticed that fluchloralin (PPI), trifluralin (PE) and pendimethalin (PE) at 1 kg ha^{-1} did not show any effect against broomrape. Similarly, Punia (2015) conducted experiments for controlling *P. aegyptiaca* in mustard during *Rabi* 2008-09 and 2009-

10 and observed that application of organic manures *viz.,* neem cake and castor cake along with hoeing or pendimethalin were not effective in controlling population of *P. aegyptiaca*.

Crop studies

The plant height presented in the table 4 increased with the advancement of crop age and reached its maximum at maturity. Significantly higher plant height *viz*. 81.5, 196.8, 231.5 and 232.7 cm at 65, 95, 130 DAS and at harvest, respectively, was recorded with the plants supplied with treatment T_9 (125% of recommended fertilizers (N and P) + foliar sprays of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively) as compared to other treatments which might be due to higher dose of N and P and excellent control of *P. aegyptiaca*. Similarly, Egley (1971) and Yaduraju *et al.* (1979) also reported the beneficial effects of nitrogenous fertilizers on improved crop performance and tolerance to the attack by the parasitic weed. Plant height in weedy check was recorded significantly lower at all the growth intervals except at 65 DAS when the plant height was at par with application of *neem* cake 400 kg ha^{-1} before sowing.

The data in the table 5 indicated that the significantly higher number of siliquae $plant^{-1}$ (306) and 1,000 -seed weight (5.42 g) at harvest stage were recorded in treatment T_9 (125% of recommended fertilizers (N and P) + foliar sprays of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively), which was statistically similar with treatment T_7 (foliar sprays of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively). Similarly, number of seeds $siliqua^{-1}$ was recorded maximum in treatment T_9 (14.1), which were at par with T_2, T_3, T_6, T_7 and T_8. The treatment T_9, because of better crop growth due to higher dose of fertilizers might have resulted in accumulation of higher siliquae $plant^{-1}$, seeds $siliqua^{-1}$ and 1,000 -seed weight.

The data pertaining to seed yield (kg ha^{-1}) and harvest index (%) of Indian mustard shown in the table 5 varied significantly due to different treatments. The maximum seed yield (2648 kg ha^{-1}) and harvest index (23.7%) was obtained with plants supplied with treatment T_9 *i.e.* 125% of recommended fertilizers (N and P) + foliar sprays of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively and was statistically at par with treatment T_7 (2426 kg ha^{-1} and 23.1%, respectively) *i.e.* foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively and significantly higher over rest of the treatments. The treatment T_9 and T_7 produced 88.7% and 72.9% more seed yield, respectively than weedy check (T_{11}). The combined effect of higher dose of fertilizers and maximum control of *P. aegyptiaca* in treatment T_9 provided ideal conditions for growth of mustard crop resulting in higher plant height, number of siliquae $plant^{-1}$, seeds $siliqua^{-1}$ and 1,000 -seed weight ultimately increased the seed yield and harvest index. The improvement in seed yield can also be attributed to the improved *P. aegyptiaca* control and soil fertility in treatment T_9 (Chen and Katan, 1980; DeVay, 1991). Pesch and Pieterse (1982) and Agabawi and Younis (1985) reported that addition of certain synthetic nitrogenous fertilizers resulted in improved crop yields due to a detrimental effect of the fertilizers on the parasitic infestation. The maximum oil content (%) was also recorded in treatment T_9 (38.7%) followed by treatment T_7, T_8 and T_3. Better conditions for crop growth *i.e.* less crop competition and addition of 125% of recommended dose of N and P led to higher seed yield and oil content.

The data in the table 5 revealed that the treatment T_3 *viz. neem* cake at 400 kg ha^{-1} at sowing followed by foliar sprays of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively caused some phyto toxicity (16.7%) in the form of elongated apical stem to mustard crop followed by treatment T_2 *i.e. neem* cake at 400 kg ha^{-1} before sowing followed by foliar spray of glyphosate at 20 and 40 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively (13.3%). None of the other treatments indicated any symptoms of phyto toxicity in mustard crop. This phyto toxicity might be due to application of higher doses of glyphosate at early stages of crop growth. Punia *et al*. (2010) observed that over dosing or early spray of glyphosate caused 15-35% toxicity to mustard *viz*. marginal leaf chlorosis, slow leaf growth and bending of apical stems and stunting along with decrease in yield. Glyphosate at 50 g ha^{-1} dose at 55 DAS caused bleaching of few leaves of mustard, which recovered within 20 days of spray resulting in no yield loss. Sauerborn *et al*. (1989) reported that glyphosate sprayed twice (when the broomrape attachments to the faba bean roots were at tubercle stage of development and after 15 days of 1st spray) at 80 g ha^{-1} caused some physiological disorder in the plant that restricted the beneficial effect of broomrape control on faba bean plants. Kumar (2002) observed that glyphosate (82 g ha^{-1} at 60 DAS) provided excellent control of broomrape without any toxic effect on mustard crop but the higher doses (123 g ha^{-1} at 60 DAS) of glyphosate showed toxicity.

Foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0 per cent solution of $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively either with 100 or 125 per cent of recommended fertilizer (N & P) maintained least population and fresh weight of *Phelipanche aegyptiaca* upto harvest and provided maximum growth, yield and oil content in mustard as well. Use of neem cake, pendimethalin and metalaxyl either alone or in combination with glyphosate proved ineffective to inhibit *P. aegyptiaca* germination. Foliar spray of glyphosate at 45 DAS showed phyto-toxicity symptoms in mustard crop that recovered within few days without causing yield losses.

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