AJES
ASIAN JOURNAL OF ENVIRONMENTAL SCIENCE
VOLUME 12 | ISSUE 1 | JUNE, 2017 | 1-22 ■ e ISSN-0976-8947 ■ Visit us : *www.researchjournal.co.in*
DOI: 10.15740/HAS/AJES/12.1/1-22

RESEARCH ARTICLE

Orobanche infestation in Indian *Brassica juncea* L. in Ajmer districts of Rajasthan and its management

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Article Chronicle :
Received :
27.03.2017;
Revised :
01.05.2017;
Accepted :
15.05.2017

Key Words :
Neem, *Orobanche, Brassica juncea,* DAS, Fertilizer

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ABSTRACT : *Orobanche aegyptiaca* started to emerge above ground 40 DAS of Indian mustard. Significant difference was observed in number of *Orobanche* shoots m^{-2}, fresh and dry weight of *Orobanche* shoots m^{-2} and visual control of *Orobanche* in mustard crop due to different treatments. At 60DAS, treatments T_3, T_7, T_8 and T_9 were observed most effective with no shoots, fresh weight and dry weight of *Orobanche* m^{-2}, hence, providing 100 per cent control of *Orobanche* at 65DAS of mustard. At 90DAS, 120DAS and harvest, treatment T_9 was found statistically at par with T_7 and T_8 in reducing the number, fresh and dry weight of *Orobanche* shoots, hence, providing the maximum visual control at 95, 125DAS and at harvest, respectively. Increasing the application of nitrogen in mustard decreased the population, fresh weight and dry weight of *Orobanche* and increased the control of *Orobanche* in T_9 over T_8 probably because of detrimental effect of the nitrogenous fertilizers on the parasitic infestation. A significant difference in plant height and dry matter accumulation plant^{-1} of mustard was observed due to different treatments. The plant height and dry matter accumulation plant^{-1} in treatment T_9 *i.e.* 125 per cent of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively was higher due to higher dose of N and P and excellent control of *Orobanche* during its life cycle. Different treatments resulted in significant difference in crop growth rate of Indian mustard from sowing upto 130DAS and thereafter it remained non-significant. Among different treatments, 125 per cent of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively (T_9) resulted in highest CGR which might be due to better control of *Orobanche* coupled with beneficial effects of higher dose of N and P on mustard at active vegetative stages as a result of enhancement in cell multiplication, cell elongation and cell expression in the plant body which ultimately increased the CGR. Among the different treatments, number of primary branches at harvest stage were found maximum in treatment T_9 which was at par with treatment T_7 but significantly higher over rest of the treatments. Number of siliquae plant^{-1} at harvest stage were recorded maximum in treatment T_9 which was at par with treatment T_7 but significantly higher over rest of the treatments. T_9 recorded maximum number of siliquae because higher nutrients help in more number of branches, mainly the secondary branches and resulting higher number of siliquae plant^{-1} at higher dose of fertilizers. Similarly, number of siliquae branch^{-1} were maximum under 125 per cent of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively (T_9) which was significantly superior over all other treatments. Maximum siliqua length (cm) and 1,000-grain weight (g) was observed with 125 per cent of recommended fertilizer + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively (T_9) which was at par with foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively (T_7) and superior over all other treatments. Similarly, grains siliqua^{-1} were recorded maximum in treatment T_9 which was found statistically at par with T_2, T_3, T_6, T_7 and T_8 and significantly higher than other treatments. Grain yield and biological yield of Indian mustard varied significantly due to different treatments. Treatment T_9 *i.e.* 125 per cent of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively, produced highest grain yield and biological yield which was at par with T_7 *i.e.* foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively. Treatment T_9 and T_7 produced 88.7 and 72.9 per cent more grain yield, respectively than weedy check (T_{11}). The combined effect of higher dose of fertilizers and maximum control of *Orobanche* in treatment T_9 provided ideal conditions for growth of mustard crop resulting in higher plant height, more primary and secondary branches $plant^{-1}$, number of siliquae $plant^{-1}$, more number of grains $siliqua^{-1}$ and higher 1000-grain weight ultimately increased the grain and biological yield.

HOW TO CITE THIS ARTICLE : Lal, Hira, Singh, Devendra and Jat, Bhanwar Lal (2017). *Orobanche* infestation in Indian *Brassica juncea* L. in Ajmer districts of Rajasthan and its management. *Asian J. Environ. Sci.*, **12**(1): 1-22, **DOI: 10.15740/HAS/AJES/12.1/1-22.**

Rapeseed-mustard (*Brassica* spp.) is a major group among oilseed crops in the world being cultivated in 53 countries across the six continents (Goyal *et al.*, 2006), with India ranking third in area and production in the world (DRMR, 2015). Indian mustard (*Brassica juncea* L. Czern) belongs to family Cruciferae, genus *Brassica* and species *Juncea*. It is an herbaceous annual plant of erect nature along with many branches. Its plant height ranges from 90- 250cm. The leaves are not dilated at the base, but are stalked, broad and pinnatified. The pods are slender, 2 to 6.5cm long, strong ascending or erect with short and stout beaks. The colour of the seed is brown or dark brown and seed coat is rough. Flower of Indian mustard have four sepals and four petals of deep yellow to pale yellow colour. Each flower has six stamens, two with short and four with long filaments. The pistil is compound and the ovary matures into a two celled fruit (siliqua). Its flower is made up of two carpels, which are separated by a false septum, providing two chambers. Its seed contains 37 to 49 per cent edible oil (Singh *et al.*, 2009). Globally, rapeseed- mustard is grown on an area of 33.64m ha with a production and productivity of 62.84 m t and 1856kg ha^{-1}, respectively (FAO STAT, 2013). There was considerable increase in productivity of mustard from 405kg ha^{-1} in 1966-67 to 1856 kg ha^{-1} in 2012-13. India accounts for 19.29 per cent and 11.13 per cent of the total acreage and production of rapeseed- mustard in the world (DRMR,2013). Productivity of rapeseed-mustard in India (1188 kg ha^{-1}) is very less as compared to world's productivity of 1856 kg ha^{-1} (Pirri and Sharma, 2006). Rapeseed-mustard crops are cultivated over an area of about 6.70m ha with production of 7.96m t in India (DES, 2015). These crops are grown in different agro climatic conditions varying from north eastern/north western hills to south under irrigated / rainfed conditions, timely sown/late sown, saline soils and mixed cropping. Indian mustard alone is grown on about 75- 80 per cent of total area (6.70m ha) under rapeseed- mustard crops. Indian mustard (*Brassica juncea* L.) is the major *Rabi* oilseed crop of South-western Rajasthan. The state Rajasthan ranks 1st in the country with area and production of rapeseed- mustard. Whereas ranks 3rd and 4th contributing 11.06 per cent (0.88m t) and 8 per cent (0.54m ha) in production and total area, respectively (DES, 2015). It is grown on an area of 0.54m ha across Bharatpur, Swaimadhopur, Alwar,Tonk, Dausa district of Rajsthan. The soils of these districts are light textured loamy to sandy loam soils characterized by poor fertility and low moisture holding capacity. Mustard crop in these areas is severely infested with a holoparasitic weed, namely broomrape (*Orobanche aegyptiaca* L.). This parasitic weed has the tendency to proliferate well in coarse textured soils with high pH, low nitrogen status and poor water holding capacity. *Orobanche aegyptiaca* has spread over an area of 0.25m ha in mustard fields of Northern-eastern Rajasthan (Punia, 2014). Broomrape or *Orobanche,* commonly known as 'Margoja', 'rukhri', 'gulli', 'khumbhi' or 'sarson ka mamma', belonging to family Orobanchaceae is an annual, branched, achlorophyllous, noxious, obligate root holoparasite that reproduces only by seeds (Saghir *et al.*, 1973; Press *et al.*, 1986 and Punia *et al.*, 2012). This parasitic weed grows on the roots of mustard plant in response to germination stimulants secreted by its roots and looks like a beautiful plant with purple coloured scales, 10-60cm in height and occasionally growing in clusters. *Orobanche* plants are without leaves and upper 2/3rd part of stem bears inflorescence which is rather sparse. Each flower bears a small capsule which contains upto 50,000 or even minute seeds. The seeds remain viable in soil for upto 20 years. *Orobanche* fulfill its entire carbon, nutrition and water requirement from the host plant with the help of haustoria which connects the host vascular system and parasite (Mabrouk *et al.*, 2010 and Gevezova *et al.,* 2012). The attached parasite functions as a strong metabolic sink, often named "super-sink", strongly competingwith the host plant for water, minerals and assimilates. The diversions of these substances to the parasitic weed causes moisture and assimilate starvation, host plant stress and growth inhibition which leads to extensive reduction in crop yield and quality in the infested fields (Punia, 2015). It causes severe damage to vegetables and field crops from numerous botanical families (Parker and Riches, 1993 and Joel *et al*., 2007). No wonders that broomrapes are called 'halook' in Egypt, which refers to ancient invaders who ransacked Egypt, and 'aleket' in Hebrew, meaning bloodsucking leeches. They cause extensive damage by reducing the yield of parasitized crops. For example, in the former USSR, *O. aegyptiaca* caused a 50 per cent reduction in yield of watermelon (*Citrullus lanatus*) (Panchenko, 1974). Yield losses have also been reported in broad bean (Mesa-Garcia *et al.*, 1984 and Zaitoun *et al.,* 1991), faba bean (Aksoy and Uygur, 2008), potato (Donogla *et al*., 2011), sunflower (Malykhin, 1974 and Shalom *et al.*, 1988), tobacco (Krishnamurthy *et al.*, 1977 and Dhanapal *et al*., 1996), tomato (Aksoy and Uygur, 2008 and Donogla *et al*., 2011) and mustard (Punia, 2015). Although it is hard to make exact estimates of the yield losses due to the difficulty in creating broomrape-free plots for comparison with infested plots. In India, *Orobanche* spp. have been reported as a main parasite of tobacco, tomato, brinjal, rapeseed mustard, cotton, jute etc. Broomrape infestations have been reported to decrease the area under cultivation of various crops. Besides causing yield loss and reduction in cultivated area of crops, broomrapes also reduce crop quality. The presence of broomrape plant material in harvested crop produce may reduce the value and marketability of the crop. For instance, in Israel, the value of hay was reduced due to the presence of broomrape stalks (Foy *et al.*, 1989). Broomrape attack resulted in yield losses as well as reduction in quality of tobacco in Cuba (Parker and Riches, 1993) and in India (Krishnamurthy *et al.,* 1977b). Broomrapes reduce the number of crop alternatives available to farmers. The presence of broomrape in a field may force farmers to plant a less economical, non-host crop or to leave the field fallow. As infestation of this weed starts after 7-10 days of sowing, the control measures should also be applied in early stages of the crop growth. Application of any control measure after panicle initiation of *Orobanche* is of no use as damage starts from 30 days after sowing while growing underneath for its initial growth stage (Punia *et al.*, 2010). Use of glyphosate in controlling *Orobanche* in Indian mustard is well documented (Sheoran *et al*., 2014 and Punia, 2015), but its application at higher dose or wrong stage may cause toxicity to mustard. The scientific management of *Orobanche aegyptiaca* in Indian mustard is necessary to improve/ maintain the productivity of the crop. Keeping these points in view, the present investigation entitled "*Orobanche* infestation in Indian mustard (*Brassica juncea* L.) in Ajmer districts of Rajsthan and its management", was planned with the following objectives:- (i) To study the *Orobanche aegyptiaca* infestation in Indian mustard in Ajmer district of Rajasthan. (ii) To study the effect of time of application of glyphosate on *Orobanche aegyptiaca* and growth and yield of mustard. (iii) To study the effect of organic manures, metalaxyl and ammonium sulphate in combination with glyphosate on *Orobanche aegyptiaca* and growth and yield of mustard. (iv) To assess the phyto-toxicity of different treatments on mustard.

EXPERIMENTAL METHODOLOGY

In order to accomplish the objectives of the study entitled "*Orobanche* infestation in Indian mustard (*Brassica juncea* L.) in Ajmer districts of Rajasthan and its management", a survey for two consecutive years and field experiment was conducted during *Rabi season* 2015-2016 and 2016-2017, respectively. The details of materials used and techniques adopted during the course of investigation are described in this chapter.

The methodological research processes adopted in conducting the present study are as under:

Experimental site and location:

Survey on *Orobanche aegyptiaca* infestation in Indian mustard was conducted in Ajmer districts of Rajsthan in *Rabi* 2016-17. The field experiment was conducted at Bhagwant University (Ajmer) in *Rabi* 2016-17 located at 25.38ºN, 73.54º E and at an altitude of 266m.

Climate and weather conditions of experimental location in brief:

The climate of Ajmer can be classified as tropical, semiarid and hot which is mainly dry with very hot summer and cold winter except during monsoon when moist air of oceanic origin penetrates into the district.

There are four seasons in a year. The hot weather season starts from mid March to last week of the June followed by the south west monsoon which lasts upto September. The transition period from September to October forms the post monsoon season. The winter season starts late in November and remains upto first week of March. The average rainfall varies from 300-500mm and the total rains as well as its distribution are subjected to great variations. About 80-90 per cent of the total rains are received from South-West monsoon during the month of July to September. The minimum temperature in this area reaches upto 0.5ºC in December and January and the maximum temperature in the area reaches up to 48ºC during May or June. Weekly and monthly weather parameters recorded at Observatory of Bhagwant University, Ajmer (Rajasthan).

Air temperature:

Weekly mean maximum temperature prevailed in *Rabi* 2016-17 (40th to 15th standard meteorological weeks) ranged from 16.1-37.7°C, whereas, the weekly mean minimum temperature varied from 1.9-21.2°C. Monthly mean maximum temperature prevailed in *Rabi* (Oct. 2016- Apr. 2017) varied between 17.4-35.0°C, whereas, the monthly mean minimum temperature ranged between 5.2-19.2°C.

Relative humidity:

The weekly morning relative humidity for the season varied from 70.0-98.4 per cent whereas the weekly evening relative humidity varied between 21.1-86.0 per cent throughout the season.

Wind velocity:

Monthly mean wind velocity for the season was 2.7km h^{-1} which was less than normal (4.0km h^{-1}). Fastest wind blew in 11th SMW with velocity of 5.1 km h^{-1}.

Sunshine hours:

The average sunshine hours during the season were 6.7 h day^{-1}, which was below normal (7.9). The maximum sunshine hours were recorded in 12th SMW (March) with a value of 9.9 h day^{-1}, while the minimum sunshine hours were recorded in 4th SMW (January) with a value of 1.8 h day^{-1}.

Pan evaporation:

The average pan evaporation was recorded as 2.7mm day^{-1}, which was less than the normal (4.2mm day^{-1}). The minimum pan evaporation was 0.7mm day^{-1} in 2nd SMW (January) and highest pan evaporation was 6.7 mm day^{-1} in 40th SMW (October).

Rainfall:

The total rainfall received at Ajmer during the *Rabi* 2016-17 was 280.3 mm which was nearly five times more than normal (61.4 mm). Average rainfall received during the season was 1.4mm day^{-1}. Crop received the maximum rainfall during 9th SMW, which was 16.5 mm day^{-1}.

Physico-chemical properties of the soil:

For mechanical and chemical analysis of soil of the experimental field, soil was taken from eight places at random from 0-15cm depth before sowing the crop. The soil taken from all places was mixed thoroughly to form composite sample which was analysed for physico-chemical properties of the soil. On the basis of mechanical and chemical analysis of soil, the soil is categorized as sandy in texture. Chemical analysis revealed that soil of the experimental field was low in organic carbon and nitrogen, medium in available phosphorus and potassium and neutral in reaction.

Experimental details:

Experiment: Survey on infestation of Egyptian broomrape (Orobanche aegyptiaca) in Indian mustard:

A survey was conducted for two consecutive years on the infestation of Egyptian broomrape (*Orobanche aegyptiaca* L.) in Indian mustard in Ajmer districts of Rajsthan. During *Rabi* 2015-16 and 2016-17. The survey was conducted by visiting fields of Indian mustard randomly in these areas from 20th March to 10th April in both the years. There are 10 and 9 blocks in Ajmer districts, respectively. 9 villages from each block of Ajmer district were selected at random. One field was surveyed from each of these villages randomly. The following information was collected from these farmers/ locations:- (i) Name and address of the farmer (ii) GPS location of the field surveyed (iii) Date of sowing of mustard (iv) Variety of mustard grown (v) Years for which mustard is grown continuously in the same field (vi) Crop rotation followed in the same field (v) Crops grown in adjoining fields (vi) Type of irrigation used in mustard crop (vii) Soil texture (viii) *Orobanche* shoots m^{-2}:- *Orobanche* density was recorded with the help of 0.5 m x 0.5m quadrant. The quadrant was thrown randomly at four places in the field and *Orobanche* shoots were counted, summed upto calculate *Orobanche* shoots m^{-2}.(ix) Infestation of *Orobanche*:-The infestation of *Orobanche* was classified as nil (0), less (between 1-20 shoots m^{-2}), moderate (between 20-50 shoots m^{-2}) and severe (more than 50 shoots m^{-2}). The data collected during the survey was analysed using the desirable statistical tools and techniques to generate fruitful inferences regarding *Orobanche* infestation in Indian mustard in Ajmer districts of Rajasthan.

Treatments:

(i) T_1 *Neem* cake 400 kg ha^{-1} at sowing. (ii) T_2 *Neem* cake 400 kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively. (iii) T_3 *Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1}+1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively. (iv) T_4 *Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2 per cent at 25DAS. (v) T_5 *Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2 per cent at 25DAS. (vi) T_6 *Neem* cake 400kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2 per cent at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS. (vii) T_7 Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively. (viii) T_8 Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25DAS and 55DAS, respectively (Recommended practice). (ix) T_9 125 per cent of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively. (x) T_{10} Hand pulling of *Orobanche* shoots at 45, 65 and 85 DAS, respectively. (xi) T_{11} Weedy check.

Chemical composition of *Neem* cake:

Neem cake was purchased from local market. *Neem* cake contained 1.15, 0.13 and 1.78 per cent N, P_2O_5 and K_2O, respectively.

Chemical properties of herbicides/ fungicides:

Brief description of herbicides/ fungicide used in the experiment is given below:

Glyphosate:

Glyphosate is a highly shoot mobile, broad-spectrum, weak residue herbicide used to kill weeds, especially annual broadleaf weeds and grasses known to compete with commercial crops grown around the globe (Gupta, 2007). It is systemic in nature. It is mainly absorbed via foliage and very less via roots (Sprankle *et al.,* 1975) and translocated to growing points. Glyphosate is an aminophosphonic analogue of the natural amino acid glycine and the name is a contraction of glycine phosphonate.

Pendimethalin :

Pendimethalin is one of the members of dinitroanilines group of herbicide and used as pre-emergence and post-emergence herbicide to control annual weeds which affects the growth, yield and quality of agricultural crops because they compete with the crops for light, nutrients and water. It is both contact and systemic in action. It controls the weed population and prevents weed emergence, especially during the most important development period of the crop.

Metalaxyl:

It is a phenylamide fungicide having systemic action.

Cultural practices done at the field: Land preparation:

After pre sowing irrigation, when the field came to better condition, 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.

Incorporation of organic manure:

Quantity of *Neem* cake required for the plot at 400kg ha^{-1} was calculated and uniformly broadcasted and incorporated into the soil before sowing.

Seed and sowing:

The mustard crop variety RH 0749 seeds were sown @ 5kg ha^{-1} by *Pora* method with the help of hand drawn plough keeping row to row distance of 45 cm on October 25, 2014.

Thinning:

Thinning of extra plants was done 20 days after sowing by hand-pulling to maintain spacing of 15cm between plants within the row as per treatment.

Fertilizer application:

The recommended doses of nitrogen (80kg N ha^{-1}) and phosphorus (30kg P_2O_5 ha^{-1}) were applied in all the treatments except T_9 in which 125 per cent of recommended doses of nitrogen (100kg N ha^{-1}) and phosphorus (37.5kg P_2O_5 ha^{-1}) were applied. Full dose of phosphorus and half dose of nitrogen were applied at sowing time and remaining half dose of nitrogen was applied after first irrigation. The sources of nitrogen and phosphorus were urea (46% N) and Diammonium phosphate (46% P_2O_5 and 18% N), respectively. The urea was applied by broadcasting and DAP was applied with the help of drill.

Herbicide/ fungicide application :

The herbicides *viz.*, glyphosate (41% SL) and pendimethalin (30 % EC) and fungicide metalaxyl (72% WP) were applied as per treatments with the help of knap sack sprayer fitted with flat fan nozzle using a spray volume of 600 l ha^{-1}.

Irrigation :

The crop was sown with pre-sowing irrigation and two post sowing irrigations were applied, one at 50 per cent flowering and second at siliqua formation stage to all the treatments as per recommendations contained in the package of practices.

Harvesting and threshing:

The crop was harvested manually with sickles. Before harvesting, five tagged plants were pulled out from each plot to record post -harvest observation. The net plots were harvested separately and left in the respective plots for sun drying. The crop was threshed with the help of mini thresher after 7-10 days of harvesting.

Observations recorded: *Orobanche* studies:
Number of Orobanche shoots emerged per m²:

The number of *Orobanche* shoots emerged was determined by quadrate method (Misra and Puri, 1954). The quadrate (0.5m x 0.5 m) was thrown randomly at four places in each plot at 60, 90, 120DAS and at harvest. The sum total of *Orobanche* shoots inside the quadrate were counted and expressed as number of *Orobanche* shoots emerged per m^2 at respective stage.

Fresh weight of *Orobanche* per m² (g):

The quadrate (0.5m x 0.5m) was thrown randomly at four places in each plot at 60, 90, 120DAS and at harvest. The *Orobanche* shoots inside the quadrate were uprooted, washed and then sun dried for 1-2 hours. Then the *Orobanche* shoots were weighed and expressed as fresh weight of *Orobanche* shoots emerged per m^2 at respective stage.

Dry weight of *Orobanche* per m² (g):

After taking the fresh weight of samples, the samples were sun dried for 2-3 days and then kept in oven at 65±5 ºC till a constant weight was achieved. The dried samples were weighed and expressed as dry weight of *Orobanche* shoots emerged per m^2 at respective stage.

Visual control of *Orobanche* (%):

The data on visual control of *Orobanche* was recorded at 40, 65, 95, 130DAS and at harvest by visually observing each plot. The control was recorded on 0-100 scale (%).

Crop studies: Growth studies: Plant height (cm):

Plant height was measured at 40, 65, 95, 130DAS and at harvest on five tagged plants in each plot. The height was measured from the base of the plant to the tip of the main stem of randomly tagged plants and mean values were calculated.

Dry matter per plant (g):

The three randomly selected plants were uprooted every time from each plot to record the dry matter production at 40, 65, 95 and 130DAS and at harvest. These samples were chopped, sundried and then kept in an oven at 65±5°C till a constant weight was achieved. The dried samples were weighed and average dry matter (g) per plant was recorded.

Crop growth rate (g m^{-2} day^{-1}):

Crop growth rate (CGR) indicates increase in dry weight (W) of plant in a unit time (T) per unit land area (P). The five randomly selected plants from each plot were used to record the dry matter production at 40, 65, 95 and 130DAS and at harvest. These samples were first sun dried and then kept in an oven at 65±5 ºC till a constant weight was achieved. The average was recorded as dry matter (g) per plant. CGR was measured at 65, 95, and 135DAS and at harvest by using the following formula (Reddy and Reddy, 2010):

$$CGR = \frac{(W_2 - W_1)}{P\,(T_2 - T_1)}$$

where, P is the land area per plant and W_1 and W_2 are dry weights of plant at T_1 and T_2 time, respectively.

Relative growth rate (mg g^{-1} day^{-1}):

Relative growth rate (RGR**)** indicates the amount of growing material per unit dry weight of plant per unit time. It is also called efficiency index. It represents the rate of growth per unit dry matter. The five randomly selected plants from each plot were used to record the dry matter production at 40, 65, 95and 130DAS and at harvest. These samples were first dried under the sun and then kept in an oven at 65±5 ºC till a constant weight was achieved. The average was recorded as dry matter g $plant^{-1}$. RGR was measured at 65, 95 and 135DAS and at harvest by the following formula (Reddy and Reddy, 2010):

$$RGR = \frac{(Log_e\ W_2 - Log_e\ W_1)}{(T_2 - T_1)}$$

where, W_1 and W_2 are dry weights of plant at T_1 and T_2 time, respectively.

Phenological observations: Days to 50 per cent flowering :

Days to 50 per cent flowering were recorded in a plot when at least one flower on main raceme of about 50 per cent plants was opened.

Days to siliqua initiation:

Days to siliqua initiation was recorded with the beginning of formation of siliqua on plants by regularly visiting the field.

Yield and yield attributes : Number of primary and secondary branches per plant:

The total numbers of primary and secondary branches produced per plant were counted at harvest on five tagged plants in each plot and their average was recorded.

Number of siliquae per plant and branch:

Total number of siliquae per plant and plant was recorded from five tagged plants at harvest and average was calculated for one plant.

Number of grains per siliqua:

Hundred siliquae were taken from five plants, threshed and cleaned. The number of grains was counted for these siliquae. The average number of grains per siliqua was worked out.

1,000 - Grain weight (g):

Random samples were collected from threshed crop of each plot. 1,000 – Grain were counted from these samples and weighed to record 1,000- Grain weight (g).

Grain yield (kg ha^{-1}):

The crop harvested from net plot was tied into bundles for weighing and sun drying. After sun drying for 7 days, crop was threshed with the help of mini thresher and yield per plot was recorded and converted into kg ha^{-1}.

Biological yield (kg ha^{-1}):

The standing stems were harvested with the help of sickle from near the ground surface, tied in bundles, sundried for one week and weighed. This was added to the dry weight of reproductive portion of crop (dry weight of crop before threshing) and converted into kg ha^{-1}.

Harvest index (HI):

Harvest index is represented in terms of percentage. The harvest index for each plot was calculated by dividing the economic (grain) yield by the biological yield (seed + stover yield) of the same net plot and multiplied by 100 as given below:

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Phyto-toxicity of different treatments on mustard (%):

The phyto-toxicity on mustard was recorded at 40 and 65DAS by visually observing each plot. The phyto-toxicity was recorded on 0-100 scale (%).

Economics:

Total cost of cultivation for Indian mustard was calculated by taking into account the recommended package and practices and adding additional cost of treatment to each treatment. For calculating gross returns, grain and stover yield of individual treatment was taken into consideration. Net returns were calculated by subtracting cost of cultivation from gross returns. B: C was calculated using following formula:

$$\mathbf{B:C = \frac{Gross\ returns}{Cost\ of\ cultivation}}$$

Statistical analysis:

All the experimental data for various crop growth studies, yield, yield attributing characters and *Orobanche* studies were analysed statistically by method of analysis of variance. The significance of difference between two treatment means *i.e.* critical difference (CD) was calculated as described by Cochran and Cox (1963).

Transformation:

Data on the number, fresh and dry weight m^{-2} and per cent weed control of *Orobanche* and phyto-toxicity showed high degree of variation. A linear relationship between the means and variance was observed and hence, the data on number, fresh and dry weight of *Orobanche* m^{-2} and phyto-toxicity were subjected to square root transformation, while data on per cent control of *Orobanche* (visual) were subjected to arc sin transformation to make analysis of variance valid. The significant difference among treatments was tested by calculating C.D. at 5 per cent (P = 0.05) level of significance. The formulae for calculating S.E(d) and C.D.are given below:

$$\mathbf{S.E.(d)} \; Z \; \frac{\sqrt{\mathbf{2EMS}}}{\mathbf{r}}$$

C. D (P = 0.05) = S.E. (d) x t value at 5 per cent error d. f. where, C. D. = Critical difference S.E. (d) = Standard error of difference EMS = Error mean square r = Number of replications.

EXPERIMENTAL FINDINGS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Experiment: Survey on infestation of Egyptian broomrape in Indian mustard year wise infestation of *Orobanche* in Ajmer districts:

Infestation of *Orobanche* in Indian mustard in the districts Ajmer over the years 2015-16 and 2016-17. In *Rabi* 2016-17, no infestation of *Orobanche* was observed in most of the area of Ajmer district except some parts of Agroha, Ajmer 1 and Ajmer 2 blocks. Moderate or severe infestation of *Orobanche* was observed in parts of Ajmer 1 and Ajmer 2 blocks adjacent to Ajmer district. Whereas, most of the Ajmer district showed severe infestation of *Orobanche* except some parts of Beawar, Rupangarh, Pushkar Nashirabad, Kekri, Kishangarh and Sarwar blocks. In *Rabi* 2015-16, no infestation of *Orobanche* was observed in most of the area of Ajmer district except some parts of Pushkar, Ajmer 1 and Ajmer 2 blocks. Moderate infestation of *Orobanche* was observed in parts of Ajmer 1 block adjacent to Ajmer district. Severe infestation of *Orobanche* was observed in parts of Ajmer 2 block of Ajmer district. Pushkar and Nashirabad blocks.

***Orobanche* infestation in different varieties:**

Mustard variety RB 50 was not grown in Ajmer in any of the years. No significant difference was observed in population of *Orobanche* among varieties grown in the region.

Effect of cropping pattern :

Perusal of the data revealed that population of *Orobanche* did not vary significantly with the continuous cultivation of mustard again and again in the same field. However generally, the infestation of *Orobanche* increased with the increase in repetition of mustard in the same field over both the years in Ajmer districts. The population of *Orobanche* increased from 9.3 to 22.5 m^{-2} and 3.1 to 7.4 m^{-2} during the years 2015-16 and 2016-17, respectively in Ajmer district. Similarly, population of *Orobanche* in Ajmer district increased from 23.7 to 42.7 m^{-2} and 26.4 to 39.0 m^{-2} in the years 2014-15 and 2015-16 respectively as the continuous cultivation of mustard in the same field ranged from less than 4 years to more than 6 years in districts.

Effect of crop in adjoining field :

The data pertaining to the effect of crop in adjoining field on *Orobanche* population is elucidated in Table 1. No significant difference in population of *Orobanche* was observed due to the crop in adjoining field.

Effect of type of irrigation:

Perusal of data revealed that least population of *Orobanche* was observed in mustard fields irrigated by flooding method over both the years in Ajmer in the year 2015-16, it was found that irrigation of mustard by sprinkler method recorded significantly more population of *Orobanche* (30.53 m^{-2}) as compared to mustard irrigated by flooding method (7.84m^{-2}). But there was no significant difference in *Orobanche* population between mustard grown in rain fed conditions and mustard irrigated by sprinkler method or mustard irrigated by flooding. Whereas in the year 2016-17, population of *Orobanche* was maximum in sprinkler irrigation (32.0m^{-2}) which was significantly higher than flooding or mustard grown in rainfed areas (3.63m^{-2}). No significant difference in *Orobanche* population was observed between mustard grown in rainfed conditions and mustard irrigated by flooding method.

Effect of soil texture :

Perusal of data revealed that there was a decreasing trend of *Orobanche* population with the decrease in size of soil particles over both the years across the district. However, maximum population of *Orobanche* was observed in sandy soils in Rajasthan as well as in Ajmer in both the years. Decrease in particle size of soil resulted in significant decrease in *Orobanche* population except the soils loamy sand and sandy loam. Minimum population of *Orobanche* was observed in loamy soils in Ajmer over the years.

Orobanche studies:

Number of Orobanche shoots (m^{-2}):

The data pertaining to number of *Orobanche* shoots per m^{-2} at various intervals of crop growth have been presented in Table 2. The data were recorded with the advancement of crop age and final observation was recorded at harvest. Significant difference was observed on number of *Orobanche* shoots at 60, 90, 120 DAS and at harvest of crop. At 40DAS, no *Orobanche* shoot was observed irrespective of any of the treatment. The shoots started to emerge above ground after 40

Table 1 : Population of *Orobanche* in Indian mustard as influenced by different cultural practices of farmers

Cultural practices		Ajmer 2015-16 Mean *Orobanche* shoots (m^{-2})	2015-16 Fcal (0.05)	2016-17 Mean *Orobanche* shoots (m^{-2})	2016-17 Fcal (0.05)
Date of Sowing	Before 15th Oct	19.17	2.51*	19.73	6.36*
	15th Oct-31st Oct	8.11		4.91	
	After 1st Nov	2.50		3.78	
Variety	RH 30	10.67	0.26	6.24	1.76
	RB 50	---		---	
	RH 0749	12.32		1.31	
	Pioneer 45J21	5.71		13.0	
Continuity of mustard in same field (Years)	< 4 years	9.31	0.93	3.21	0.24
	4-6 years	14.0		5.75	
	>6 years	22.50		7.44	
Previous crop	Cotton	0.0	2.10*	1.2	1.70*
	Cluster bean	11.41		6.40	
	Pearl millet	17.28		20.34	
	Moong bean	26.39		3.15	
	Fallow	5.41		4.06	
Crop in adjoining field	Mustard	13.12	2.20	6.56	0.04
	Wheat	4.09		5.1	
	Gram	23.0		7.42	
Type of irrigation	Flooding	7.84	5.55*	1.50	16.11*
	Sprinkler	30.53		32.0	
	Rain fed	12.33		3.63	
Soil texture	Sandy	18.61	5.54*	21.35	9.71*
	Loamy sand	5.08		3.76	
	Sandy loam	3.15		2.46	
	Loamy	0.0		0.06	

* indicate significance of value at P=0.05

DAS. At 60DAS, most effective treatments in controlling *Orobanche* population were T_3, T_7, T_8 and T_9 with no *Orobanche* shoots m^{-2} followed by T_2 with only 1.7 shoots m^{-2}. At 90DAS, no *Orobanche* population was recorded in T_9 which was statistically at par with T_7 and T_8 and significantly lower than all other treatments whereas, treatment T_{11} *viz.*, weedy check was observed least effective in reducing *Orobanche* shoots (13.7) which was statistically at par with treatment T_1 (10.3) and significantly higher as compared to all other treatments. At 120DAS, minimum *Orobanche* population was recorded in T_9 0.6 which was statistically at par with T_7 and T_8 4.2 and 5.3, respectively and significantly lower than all other treatments. Whereas, treatment T_{11} 77.1 was found to be having highest population of *Orobanche* shoots which was statistically at par with treatment T_{10} , T_1 T_4 and T_5 68.4, 67.6, 59.7, respectively and significantly higher as compared to all other treatments. Similarly, at harvest, minimum *Orobanche* population was recorded in T_9 0.3 which was statistically at par with T_7 1.4 and T_8 2.3 and significantly lower than all other treatments. Whereas, highest population of *Orobanche* was observed in treatment T_{11} 37.0 which was found to be statistically at par with treatment T_{10}, T_1, T_4 and T_5 31.7, 30.1, 28.3 and 27.6, respectively and found significantly higher than other treatments.

Dry weight of *Orobanche* shoots (g m^{-2}):

The data pertaining to dry weight of *Orobanche* shoots at various intervals of crop growth are elucidated in Table 3. Significant difference was observed on dry weight of *Orobanche* shoots at 60, 90, 120 DAS and at harvest of crop. Treatment T_9 was found to be most effective in reducing the dry weight of *Orobanche* shoots in mustard crop. The shoots started to emerge above ground 40 DAS. At 60 DAS, no dry weight of *Orobanche* shoots was observed in treatments T_9, T_3, T_7 and T_8 which was found statistically at par with treatment T_2 and significantly lower than other treatments. Dry weight of *Orobanche* was found maximum in treatment T_{11} which was statistically at par with treatment T_1 and T_{10} and significantly higher than other treatments. At 90DAS, no dry weight of *Orobanche* was recorded in T_9 which was statistically at par with T_7 and T_8 and significantly lower than all other treatments. Whereas, highest dry weight of *Orobanche* was observed in treatment T_{11} which was

Table 2 : Number of *Orobanche* shoots (m^{-2}) as influenced by different treatments

Treatments		*Orobanche* shoots (m^{-2}) 40 DAS	60 DAS	90 DAS	120 DAS	Harvest
T_1	*Neem* cake 400kg ha^{-1} at sowing	---	3.6 (10.3)	5.6 (29.0)	8.4 (67.6)	5.6 (30.1)
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	---	1.5 (1.7)	3.2 (9.0)	5.2 (29.1)	3.9 (14.4)
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	---	1.1 (0)	2.4 (5.0)	4.5 (18.4)	2.8 (8.2)
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	---	3.2 (9.7)	5.1 (24.0)	7.6 (59.7)	5.6 (28.3)
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	---	2.2 (6.7)	4.72 (22.0)	7.7 (58.4)	5.4 (27.6)
T_6	*Neem* cake 400kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	---	2.4 (4.3)	4.3 (16.7)	7.2 (50.1)	5.0 (23.4)
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55 DAS, respectively	---	1.1 (0)	1.7 (1.7)	2.3 (4.2)	1.6 (1.4)
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55 DAS, respectively (Recommended practice)	---	1.0 (0)	1.6 (2.0)	2.5 (5.3)	1.6 (2.3)
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55 DAS, respectively	---	1.0 (0)	1.0 (0)	1.1 (0.6)	1.2 (0.3)
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively	---	2.8 (7.3)	2.4 (4.3)	8.4 (68.4)	5.6 (31.7)
T_{11}	Weedy check	---	3.9 (13.7)	6.2 (36.3)	8.7 (77.1)	6.3 (37.0)
S.E.±		---	0.2	0.3	0.6	0.5
C.D. (P = 0.05)		---	0.7	0.8	1.5	1.1

Original data were subjected to square root transformation $\sqrt{(X+1)}$ and presented in parentheses statistically at par with T_1 and was significantly higher as compared to other treatments. At 120 DAS, minimum dry weight of *Orobanche* was recorded in T_9 which was statistically at par with T_7 and T_8 and significantly lower than all other treatments. Whereas, treatment T_{11} was found to be having maximum dry weight of *Orobanche* shoots which was statistically at par with treatment T_{10}, T_1 and T_4 and significantly higher as compared to other treatments. Perusal of data presented in Table 4 revealed that per cent weed control of *Orobanche* was significantly affected by different treatments. Visual observation revealed that treatment T_9 *viz.*, 125 per cent of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively provided 98.3 per cent control of *Orobanche* till harvest of mustard crop. Least control of *Orobanche* was observed in treatment T_{11} *i.e.* weedy check at all the growth stages. However, upto 65DAS, treatments T_3, T_7, T_8 and T_9 provided 100 per cent control of *Orobanche* which was statistically at par with treatment T_2 and significantly higher than other treatments. Whereas, least control of *Orobanche* was observed in treatment T_{11} which was found significantly lower than all other treatments. Treatment T_9 gave highest control of *Orobanche* at 95DAS, 130DAS and harvest which was found to be statistically at par with treatments T_7 and T_8 and significantly higher than other treatments.

Crop studies:

At 65DAS, maximum plant height was observed in T_9 which was statistically at par with T_7, T_8 and T_3 but significantly superior over all other treatments. Minimum plant height was observed in T_{11} which was statistically at par with T_1 (69.3cm), T_{10}, T_4 and T_5 but significantly lower than other treatments. At 95, 130DAS and at harvest, plant height of mustard plants was highest in T_9 which was statistically at par with treatments T_7, T_8 and T_3 and was significantly superior over other treatments. Minimum plant height was recorded in T_{11} which was statistically at par with treatments T_{10}, T_1, T_4 and T_5 but significantly lower than all other treatments. Effect of different treatments on plant height of mustard recorded at different intervals of crop growth is given in Table 5. The plant height increased with the advancement of crop age and reached its maximum at maturity. Plant height

Table 3: Dry weight of *Orobanche* shoots (g m^{-2}) as influenced by different treatments

Treatments		Dry weight of *Orobanche* shoots (g m^{-2})				
		40 DAS	60 DAS	90 DAS	120 DAS	Harvest
T_1	*Neem* cake 400kg ha^{-1} at sowing		3.1(8.6)	5.3 (26.9)	8.2 (67.4)	5.2 (25.9)
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively		1.4 (1.1)	3.0 (8.0)	5.2 (26.3)	3.6 (12.4)
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively		1.0 (0)	2.5 (5.7)	4.2 (17.3)	2.7 (7.1)
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS		3.0 (8.0)	4.8 (21.8)	7.6 (57.3)	5.1(25.2)
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25 DAS		2.5 (5.5)	4.6 (20.2)	7.3 (53.8)	5.0(24.3)
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25 DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS		2.1(3.5)	3.8(14.0)	6.8 (46.0)	4.7(21.3)
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30 DAS and 55DAS, respectively		1.0 (0)	1.6(1.7)	2.1 (3.4)	1.5 (1.1)
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55 DAS, respectively (Recommended practice)		1.0 (0)	1.7(2.0)	2.6 (5.9)	1.6 (1.9)
T^9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55 DAS, respectively		1.0 (0)	1.0 (0)	1.3 (0.8)	1.1 (0.3)
T^{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively		2.7(6.2)	2.3(4.5)	8.4 (70.6)	5.3(26.9)
T^{11}	Weedy check		3.5(11.5)	6.1(36.4)	9.0(80.3)	5.6(30.6)
S.E.±			0.2	0.3	0.5	0.4
C.D. (P = 0.05)			0.5	0.9	1.5	1.1

Original data were subjected to square root transformation $\sqrt{(X+1)}$ and presented in parentheses was affected significantly due to different treatments at 40, 65, 95, 130DAS and at harvest of crop. Maximum plant height 34.1, 81.5, 196.8, 231.5 and 232.7 cm was recorded at 40, 65, 95, 130DAS and at harvest, respectively, in treatment T_9. Plant height was recorded to be minimum in T_{11} at all the growth intervals. At 40 DAS, maximum plant height was observed in T_9 which was statistically at par with all other treatments except T_{11} and T_{10}. Minimum plant height was recorded in T_{11} which was found statistically at par with T_{10} and was significantly lower than all other treatments.

Dry matter plant^{-1} (g):

The data pertaining to dry matter accumulation per plant at various intervals of crop growth have been presented in Table 6. A progressive increase in dry matter accumulation was recorded with the advancement of crop age and reached maximum at harvest, irrespective of the treatments. Significant difference among different treatments was observed on dry matter accumulation at 40, 65, 95, 130DAS and at harvest of crop. At 40DAS, treatment T_9 was observed to accumulate highest dry matter which was significantly superior over other treatments followed by T_7 and T_8. The lowest dry matter accumulation was recorded in T_{11} treatment which was statistically at par with T_{10}, T_1, T_4, T_5 and T_6 but was significantly lower than all other treatments. At 65DAS, highest dry matter accumulation was recorded in the treatment T_9 which was statistically at par with T_7 but significantly superior over all other treatments. The lowest dry matter accumulation was recorded in treatment T_{11} which was statistically at par with T_{10}, T_1, T_4, T_5, T_6 and T_2 but was significantly lower than other treatments. Dry matter accumulation was affected significantly due to different treatments at 95DAS. Dry matter accumulation was highest in T_9 which was statistically at par with T_7 and T_8 treatments but significantly superior than other treatments. However, lowest dry matter accumulation was recorded in T_{11} which was statistically at par with T_{10}, T_1, T_4, T_5, T_6 and T_2 but was significantly lower than other treatments. The data recorded for crop growth rate at different intervals of crop growth are presented in Table 7. An increase in CGR was observed with the advancement of crop age

Table 4 : Visual control of *Orobanche* as influenced by different treatments

Treatments		Visual control of *Orobanche* (%) 40 DAS	65 DAS	95 DAS	130 DAS	Harvest
T_1	*Neem* cake 400kg ha^{-1} at sowing	90(100)	20.0 (16.7)	13.1 (13.3)	11.1 (10.0)	11.1 (10.0)
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	90 (100)	73.5 (88.3)	59.0 (73.3)	51.1 (60.0)	50.5 (58.3)
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively	90 (100)	90 (100)	66.8 (83.3)	60.7 (75.0)	60.7 (75.0)
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	90 (100)	29.0 (31.7)	31.9 (28.3)	21.9 (20.0)	19.9 (16.7)
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	90 (100)	43.9 (48.3)	32.3 (30.0)	24.0 (23.3)	25.4 (20.0)
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	90 (100)	56.3 (68.3)	43.1 (46.7)	33.3 (31.7)	32.9 (30.0)
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	90 (100)	90 (100)	79.5 (95.0)	75.2 (93.3)	75.2 (93.3)
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	90 (100)	90 (100)	79.5 (95.0)	73.4 (91.7)	76.2 (91.7)
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	90 (100)	90 (100)	90 (100)	85.7 (98.3)	85.7 (98.3)
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively	90 (100)	40.7 (43.3)	61.7 (76.7)	11.1 (10.0)	11.1 (10.0)
T_{11}	Weedy check	90 (100)	0 (0)	0 (0)	0 (0)	0 (0)
S.E.±		----	6.6	5.7	7.4	7.2
C.D. (P = 0.05)		-----	19.5	17.0	21.9	21.3

Table 5 : Plant height (cm) of Indian mustard at different growth intervals as influenced by different treatments

Treatments		Plant height (cm)				
		40 DAS	65 DAS	95 DAS	130 DAS	Harvest
T_1	*Neem* cake 400kg ha^{-1} at sowing	31.7	69.3	175.2	202.6	203.4
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	33.1	74.8	185.0	217.4	219.0
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	33.3	75.8	187.8	219.9	221.7
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	32.6	71.2	176.9	204.6	205.8
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	32.6	71.4	177.9	206.1	207.1
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	32.8	73.6	181.4	211.6	212.7
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	33.7	77.2	189.8	222.9	224.6
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	33.5	76.7	188.7	221.5	223.4
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	34.1	81.5	196.8	231.5	232.7
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively	31.1	70.3	174.8	202.3	203.2
T_{11}	Weedy check	28.4	66.8	169.0	197.2	198.1
S.E.±		1.0	2.2	3.2	3.9	3.7
C.D. (P = 0.05)		2.9	6.4	9.6	11.7	11.1

Table 6 : Dry matter accumulation $plant^{-1}$ (g) of Indian mustard at different growth intervals as influenced by different treatments

Treatments		Dry matter accumulation $plant^{-1}$ (g)				
		40 DAS	65 DAS	95 DAS	130 DAS	Harvest
T_1	*Neem* cake 400kg ha^{-1} at sowing	3.68	9.48	37.14	51.64	54.38
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	3.90	10.62	43.90	63.90	67.07
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	4.00	10.96	45.24	65.88	69.30
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	3.70	9.63	38.15	53.85	56.72
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	3.76	9.92	39.48	55.52	58.46
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	3.84	10.29	40.29	57.77	60.76
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	4.19	11.81	50.04	71.31	74.91
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	4.13	11.66	48.48	69.35	73.20
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	4.62	13.42	57.11	78.64	82.84
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively	3.66	9.43	36.67	50.77	53.41
T_{11}	Weedy check	3.53	9.01	34.71	46.31	48.72
S.E.±		0.12	0.54	3.41	3.92	3.77
C.D. (P = 0.05)		0.36	1.62	10.12	11.65	11.18

and reached maximum between 65 - 95DAS and declined afterwards. Significant difference in CGR was observed between all the crop growth periods except between 130DAS to harvest. Between sowing to 40DAS, highest CGR was observed in treatment T_9 which was significantly superior over all the other treatments. Lowest CGR was recorded in T_{11} (1.96) which was statistically at par with T_{10}, T_1, T_4, T_5 and T_6 and significantly lowers than other treatments. Significant difference was found in CGR between 40- 65DAS as affected by different treatments. Maximum CGR was recorded in T_9 which were statistically at par with T_7 and T_8 and significantly higher than all other treatments. CGR was found to be minimum in T_{11} which was statistically at par with T_{10}, T_1, T_4, T_5, T_6 and T_2 and was significantly lower than other treatments. CGR was found to be significantly different between 65- 95DAS as affected by different treatments. Maximum CGR was observed in T_9 which were statistically at par with T_7 and T_8 and significantly higher than all other treatments. Whereas, minimum CGR was recorded in treatment T_{11} was statistically at par with T_{10}, T_1, T_4, T_5, T_6, T_2 and T_3 and significantly lower than other treatments. Between 95- 130DAS, highest CGR recorded in T_9 was statistically at par with T_7, T_8, T_3 and T_2 and significantly superior over all other treatments. CGR was lowest in treatment T_{11} which was statistically at par with T_{10} and T_1 significantly lower than all other treatments. No significant difference was observed in CGR between 130DAS and harvest. But numerically, CGR was highest and lowest in T_9 and T_{11}, respectively. The data pertaining to relative growth rate between various intervals of crop growth as influenced by different treatments have been presented in Table 8. An increase in RGR was observed with the advancement of crop age and reached maximum at 65- 95DAS and declined afterwards. Differences in RGR during all the stages of crop growth were found to be non-significant in relation to different treatments. A perusal of data given in Table 9 indicated that differences in days taken to 50 per cent flowering and siliqua initiation were non-significant in relation to different treatments. Treatment T_{11} took more days to 50 per cent flowering than all other treatments. However, treatment T_9 took minimum days to 50 per cent flowering. On the other hand, the treatments T_1, T_{10} and T_{11} took more days to siliqua initiation as compared to other treatments, while, treatment T_9 took least days to siliqua initiation.

Table 7 : Crop growth rate (g m^{-2} day^{-1}) of Indian mustard at different growth intervals as influenced by different treatments

Treatments		Plant height (cm)				
		0-40 DAS	40-65 DAS	65-95 DAS	95-130 DAS	130DAS Harvest
T_1	*Neem* cake 400kg ha^{-1} at sowing	2.04	5.16	20.49	9.20	1.74
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	2.17	5.97	24.65	12.70	2.01
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	2.22	6.19	25.40	13.10	2.17
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	2.06	5.28	21.13	9.97	1.82
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	2.09	5.47	21.90	10.18	1.86
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	2.13	5.74	22.22	11.10	1.90
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	2.33	6.78	28.32	13.51	2.28
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	2.30	6.69	27.28	13.25	2.44
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	2.57	7.83	32.36	13.67	2.67
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively	2.03	5.13	20.18	8.95	1.68
T_{11}	Weedy check	1.96	4.87	19.03	7.37	1.53
S.E.±		0.07	0.39	2.21	0.66	0.40
C.D. (P = 0.05)		0.20	1.16	6.55	1.96	NS

NS= Non-significant

Number of primary and secondary branches plant^{-1}:

The data pertaining to number of primary and secondary branches at harvest as influenced by different treatments have been presented in Table 10. Significant difference was observed on number of primary and secondary branches plant^{-1} at harvest of crop. Maximum primary branches at harvest were recorded in treatment T_9 which was statistically at par with T_7 and significantly higher than all other treatments. Primary branches were found to be minimum in T_{11} which was statistically at par with T_1, T_4 and T_{10} and was significantly lower than other treatments. Secondary branches were found to be maximum in treatment T_9 which was statistically at par with T_7, T_8, T_3 and T_2 and significantly higher than other treatments. Secondary branches were found to be minimum in T_{11} which was statistically at par with T_{10}, T_1 and T_4 and significantly lower than other treatments.

Number of siliquae plant^{-1}:

The data recorded for number of siliquae plant^{-1} as influenced by different treatments are presented in Table 10. Number of siliquae plant^{-1} at the time of harvest of crop varied significantly among different treatments. Number of siliquae plant^{-1} at harvest were observed to be maximum in treatment T_9 which was statistically at par with T_7 and significantly higher than all other treatments. Number of siliquae at harvest were recorded minimum in T_{11} which was statistically at par with T_{10}, T_1 and T_4 and was significantly lower than other treatments.

Number of siliquae branch^{-1}:

The data recorded for number of siliquae branch^{-1} as influenced by different treatments are presented in Table 10. Number of siliquae branch^{-1} at the time of harvest of crop varied significantly among different treatments. Number of siliquae branch^{-1} at harvest were observed to be maximum in treatment T_9 which was statistically at par with T_7 and significantly higher than all other treatments. While, minimum number of siliquae branch^{-1} at harvest were recorded in T_{11} which was statistically at par with T_{10}, T_1, T_4 and T_5 and was significantly lower than other treatments.

Siliqua length (cm):

Perusal of data presented in Table 10 revealed that siliqua length was found to differ significantly due to

Table 8 : Relative growth rate (mg g^{-1} day^{-1}) of Indian mustard at different growth intervals as influenced by different treatments

Treatments		Relative growth rate (mg g^{-1} day^{-1})			
		40-65 DAS	65-95 DAS	95-130 DAS	130 DAS Harvest
T_1	*Neem* cake 400kg ha^{-1} at sowing	16.41	19.72	4.22	0.63
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	17.40	20.50	4.58	0.61
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	17.33	20.93	4.58	0.62
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	16.60	19.67	4.35	0.63
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	16.79	19.86	4.28	0.63
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	17.11	19.63	4.50	0.63
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	18.02	20.71	4.44	0.64
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	18.11	20.58	4.34	0.68
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	18.48	20.83	4.02	0.66
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively	16.40	19.65	4.06	0.62
T_{11}	Weedy check	16.29	19.58	3.62	0.63
S.E.±		0.67	0.64	0.25	0.12
C.D. (P = 0.05)		NS	NS	NS	NS

NS= Non-significant

different treatments. Maximum siliqua length was recorded in treatment T_9 which was statistically at par with T_7 and T_8 and significantly higher than all other treatments which was significantly higher than all other treatments. Whereas, siliqua length was observed to be minimum in T_{11} which was statistically at par with T_{10} and T_1 and was significantly lower than other treatments.

Number of grains siliqua^{-1}:

The data pertaining to number of grains siliquae^{-1} as influenced by different treatments have been presented in Table 10. Significant difference was observed on number of grains siliquae^{-1} at harvest of crop. Maximum number of grains siliquae^{-1} was recorded in T_9 which was statistically at par with T_7, T_8, T_3 T_2 and T_6 and significantly higher than other treatments. Whereas, number of grains siliquae^{-1} were found to be minimum in T_{11} which was statistically at par with T_{10}, T_1, T_4 and T_5 and was significantly lower than other treatments.

1,000- Grain weight (g):

The data pertaining to 1,000- grain weight presented in Table 10 was found to be significant as influenced by different treatments. 1000- Grain weight was observed to be maximum in treatment T_9 *viz.*, 125% of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively which was statistically at par with T_7 *i.e.* foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30 and 55DAS, respectively and significantly superior over other treatments. The lowest 1000- grain weight was recorded in treatment T_{11} *i.e.* weedy check, which was statistically at par with T_{10}, T_1, T_4 and T_5 but significantly lower than all other treatments.

Grain yield (kg ha^{-1}):

The data pertaining to grain yield presented in Table 11 revealed that there was significant difference in grain yield as influenced by different treatments. Maximum grain yield was recorded in treatment T_9 *viz.*, 125% of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively which was statistically at par with T_7 *i.e.* foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30 and 55DAS, respectively and significantly superior over other treatments. Grain yield was observed to be minimum in treatment T_{11} *i.e.* weedy check which was statistically

Table 9 : Days to 50 per cent flowering and days to siliqua initiation of Indian mustard as influenced by different treatments

Treatments		Days to 50 % flowering	Days to siliqua initiation
T_1	*Neem* cake 400kg ha^{-1} at sowing	59.7	74.8
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	58.3	73.3
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	58.3	73.3
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	59.7	74.3
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	59.0	74.3
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	59.0	74.3
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	58.3	72.7
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	58.3	72.7
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	57.0	72.4
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively	59.7	74.8
T_{11}	Weedy check	60.4	74.8
S.E.±		1.0	0.8
C.D. (P = 0.05)		NS	NS

NS= Non-significant

at par with T_{10}, T_1 and T_4 and was significantly lower than other treatments.

Biological yield (kg ha^{-1}):

The data pertaining to biological yield as influenced by different treatments have been presented in Table 11. Significant differences were observed in biological yield of crop among different treatments. Treatment T_9 *i.e.* 125% of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively gave maximum biological yield (11176 kg ha^{-1}) which was statistically at par with T_7 *i.e.* foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30 and 55DAS, respectively and significantly higher than other treatments. Whereas, lowest biological yield was recorded in T_{11} *i.e.* weedy check, which was statistically at par with T_{10}, T_1 and T_4 and was significantly lower than other treatments?

Harvest index (%):

Perusal of data presented in Table 11 revealed that harvest index was maximum in treatment T_9 *i.e.* 125% of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively which was statistically at par with T_7 *viz.* foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and

Table 10 : Yield attributes of Indian mustard as influenced by different treatments

Treatments		Number of branches at harvest		Number of siliquae plant^{-1}	Number of siliquae branch^{-1}	Siliqua length (cm)	Grains siliqua^{-1}	1,000 - grain weight (g)
		Primary	Secondary					
T_1	*Neem* cake 400kg ha^{-1} at sowing	6.1	11.8	208	11.8	4.6	12.8	4.55
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	6.6	13.4	264	13.2	5.1	13.5	4.87
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	6.7	13.6	271	13.4	5.3	13.7	4.98
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	6.0	12.1	211	11.8	4.7	12.9	4.54
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	6.2	12.5	225	12.2	4.8	13.0	4.61
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	6.2	12.7	235	12.5	4.8	13.4	4.69
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	6.8	14.0	284	13.7	5.4	13.9	5.19
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	6.7	13.9	278	13.6	5.4	13.8	5.08
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	7.2	14.4	306	14.4	5.6	14.1	5.43
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively	6.0	11.7	205	11.7	4.6	12.7	4.54
T_{11}	Weedy check	5.6	11.1	192	11.6	4.4	12.3	4.35
S.E.±		0.1	0.3	9.0	0.2	0.1	0.3	0.10
C.D. (P = 0.05)		0.3	1.0	26	0.7	0.2	0.8	0.27

55DAS, respectively and significantly higher than all other treatments. Minimum harvest index was recorded in T_{11} *i.e.* weedy check, which was significantly lower than all the treatments except T_{10} and T_1. The data pertaining to oil content and oil yield of mustard have been presented in Table 12. Oil content and oil yield of mustard crop varied significantly due to different treatments. Oil content was recorded to be highest in treatment T_9 which was statistically at par with T_7, T_8, T_2 and T_3 and significantly superior over other treatments. Whereas, lowest oil content was found in treatment T_{11}, which was statistically at par with T_1, T_{10} and T_4 and was significantly lower than other treatments. Oil yield was observed to be maximum (1025kg ha^{-1}) in treatment T_9 *i.e.* 125% of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0 per cent solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively which was statistically at par with T_7 and significantly higher than all other treatments. Whereas, oil yield was recorded minimum in treatment T_{11} *i.e.* weedy check which was statistically at par with T_{10}. Visual phyto-toxicity recorded at various stages of crop growth is shown in Table 13. At 40DAS, no phyto-toxicity was observed on crop due to any treatment, but at 65DAS, mustard crop in treatment T_3 showed some phytotoxicity (16.6%) which was statistically at par with treatment T_2 (13.2%) and significantly higher than all other treatments. All the treatments except T_3 and T_2 did not exhibit any phyto-toxicity even at 65DAS. Mustard crop in T_2 and T_3 recovered from this injury within few days.

Economics:

Maximum B:C was recorded under treatment T_9 *i.e.* 125% of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively followed by T_7 *i.e.* foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30 and 55DAS, respectively and lowest with T_{10}. The B:C was lowest in T_{10} because of higher cost of manual weeding. Data pertaining to economics of different treatments are presented in Table 14. Gross returns, net returns and B:C were influenced by different treatments. Maximum gross returns (Rs. 86912ha^{-1}) were found in treatment T_9 *i.e.* 125% of recommended fertilizer + foliar spray of glyphosate at

Table 11 : Seed yield, biological yield and harvest index of Indian mustard as influenced by different treatments

Treatments		Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1	*Neem* cake 400kg ha^{-1} at sowing	1532	7324	21.0
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	2147	9497	22.6
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	2238	9800	22.8
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	1567	7390	21.2
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	1694	7874	21.5
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	1782	8197	21.7
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	2426	10488	23.1
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	2308	10070	22.9
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	2648	11176	23.7
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively	1519	7250	20.9
T_{11}	Weedy check	1403	6914	20.3
S.E.±		76	254	0.2
C.D. (P = 0.05)		225	754	0.7

25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively followed by T_7 *i.e.* foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30 and 55DAS, respectively and lowest with T_{11}. Similarly, maximum net returns were obtained in treatment T_9 *viz.*, 125% of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively followed by treatment T_7 *i.e.* foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30 and 55DAS, respectively and T_4 and was significantly lower than other treatments. At 120DAS, minimum fresh weight of *Orobanche* was recorded in T_9 which was statistically at par with T_7 and significantly lower than all other treatments. Whereas, treatment T_{11} was found to be having maximum fresh weight of *Orobanche* shoots (293.3g m^{-2}) which was statistically at par with treatment T_{10}, T_1, T_4 and T_5 and significantly higher as compared to other treatments. Similarly, at harvest, minimum fresh weight of *Orobanche* was recorded in T_9 which was statistically at par with T_7 and T_8 and significantly lower than all other treatments. Whereas, maximum fresh weight of *Orobanche* was observed in treatment T_{11} which was found statistically at par with treatment T_{10}, T_1, T_4, T_5 and T_6 and was significantly higher than other treatments. Similarly, at harvest, minimum dry weight of *Orobanche* was recorded in T_9 which was statistically at par with T_7 and T_8 and significantly lower than all other treatments. Whereas, maximum dry weight of *Orobanche* was observed in treatment T_{11} which was found statistically at par with treatment T_{10}, T_1 (25.8g m^{-2}), T_4, T_5 and T_6 and was significantly higher than other treatments. At 130DAS, T_9 was observed to accumulate highest dry matter which was statistically at par with T_7 and T_8 but significantly superior over other treatments. The lowest dry matter accumulation was recorded in T_{11} which was statistically at par with T_{10}, T_1, T_4, T_5 and T_6 but was significantly lower than other treatments. At harvest stage, highest dry matter accumulation was recorded in T_9 and was statistically at par with treatments T_7 and T_8, but was significantly superior over remaining treatments. However, lowest amount of dry matter accumulation was observed under T_{11} which was statistically at par with treatments T_{10}, T_1, T_4 and T_5 and was significantly lower compared to other treatments (Abebe *et al.*, 2013; Dinesha *et al.*, 2012; Donogla *et al.*,2011 and Punia *et al.*, 2010).

Conclusion :

The present study on *Orobanche* infestation in Indian mustard in Ajmer districts of Rajasthan and its management was conducted with objectives to survey the *Orobanche* infestation in districts and to examine the effects of different treatments on *Orobanche* and growth and yield of mustard. For accomplishment of objectives of the study, a survey was conducted for two

Table 12 : Oil content and oil yield of Indian mustard as influenced by different treatments

Treatments		Oil content (%)	Oil yield (kg ha^{-1})
T_1	*Neem* cake 400kg ha^{-1} at sowing	37.8	579
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	38.4	823
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	38.3	858
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	37.8	593
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	38.1	645
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	38.2	681
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	38.7	936
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	38.6	889
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	38.9	1025
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85DAS, respectively	37.7	574
T_{11}	Weedy check	37.6	528
S.E.±		0.1	30.0
C.D. (P = 0.05)		0.3	89.0

consecutive years during *Rabi* 2015-16and 2016-17 in Ajmer districts of Rajasthan and a field experiment was conducted during *Rabi* 2016-17 Bhagwant University, Ajmer. The field experiment was conducted in Randomized Block Design, comprising of 11 treatments with different combinations of glyphosate, *Neem* cake, pendimethalin, metalaxyl and fertilizer dose along with hand pulling and weedy check, replicated thrice.

Survey of *Orobanche* :

The infestation of *Orobanche* was more in Ajmer district whereas, no significant difference was observed

Table 13 : Visual phyto-toxicity (%) on Indian mustard as influenced by different treatments

Treatments		Visual phyto-toxicity (%)	
		40DAS	65DAS
T_1	*Neem* cake 400kg ha^{-1} at sowing	----	1.0 (0)
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	----	3.8 (13.2)
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	----	4.2 (16.6)
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	----	1.0 (0)
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	-----	1.0 (0)
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	-----	1.0 (0)
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	-----	1.0 (0)
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	-----	1.0 (0)
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	-----	1.0 (0)
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85DAS, respectively	----	1.0 (0)
T_{11}	Weedy check	-----	1.0 (0)
S.E.±		----	0.1
C.D. (P = 0.05)		-----	0.4

Table 14 : Total cost, gross returns, net returns and BC ratio of Indian mustard as influenced by different treatments

Treatments		Total cost (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
T_1	*Neem* cake 400kg ha^{-1} at sowing	41733	51916	10182	1.24
T_2	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	41838	71131	29292	1.70
T_3	*Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively	41849	73997	32148	1.77
T_4	*Neem* cake 400kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	43238	52861	9623	1.22
T_5	*Neem* cake 400kg ha^{-1} followed by pendimethalin (PPI) at 0.75kg ha^{-1} followed by soil application of metalaxyl 0.2% at 25DAS	43512	56861	13349	1.31
T_6	*Neem* cake 400 kg ha^{-1} at sowing followed by soil application of metalaxyl 0.2% at 25DAS followed by foliar spray of glyphosate at 40g ha^{-1} at 45DAS	43266	59633	16367	1.38
T_7	Foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25-30DAS and 55DAS, respectively	33489	79919	46430	2.39
T_8	Foliar spray of glyphosate at 25 and 50g ha^{-1} at 25-30DAS and 55DAS, respectively (Recommended practice)	33426	76202	42776	2.28
T_9	125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25DAS and 55DAS, respectively	34107	86912	52805	2.55
T_{10}	Hand pulling of *Orobanche* shoots at 45,65 and 85 DAS, respectively	44346	51349	7003	1.16
T_{11}	Weedy check	33373	47695	14321	1.43

in infestation of *Orobanche* in year/ *Rabi* 2015-16 and 2016-17 in districts. Delay in date of sowing of mustard reduced the population of *Orobanche* significantly in the districts. The infestation of *Orobanche* was found to be significantly affected by type of irrigation and soil texture in districts during both the years. Maximum population of *Orobanche* was observed in pearl millet mustard crop rotation whereas minimum infestation was found in cotton- mustard crop rotation in districts during both years. The population of *Orobanche* increased with increase in number of years of continuous cultivation of mustard in the same field, but this increase was statistically non-significant. Among different varieties of mustard, none were found to be resistant or tolerant to *Orobanche* infestation**.** Crops in adjoining field did not influence the *Orobanche* population in mustard.

Management of *Orobanche*:-

Orobanche studies :

Application of 125% of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively; foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively; foliar spray of glyphosate at 25 and 50g ha^{-1} at 25DAS and 55DAS, respectively (recommended practice) recorded more than 90 per cent visual control of *Orobanche* resulting in significantly lower population m^{-2} as well as fresh and dry weight of *Orobanche* g m^{-2} upto harvest. Use of *Neem* cake, pendimethalin and metalaxyl either alone or in combination with glyphosate proved ineffective to inhibit *Orobanche* germination.

Crop studies:

Growth studies:

Application of 125% of recommended fertilizers + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0 % solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively resulted in maximum plant height and dry matter accumulation $plant^{-1}$ of mustard at all the growth intervals. Different treatments resulted in significant difference in crop growth rate from sowing upto 130DAS and thereafter, it remained non-significant. Among all the treatments, 125 per cent of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively resulted in highest CGR. No significant difference was observed in relative growth rate of Indian mustard due to different treatments at any of the growth interval.

Phenological observations:

Effect of different treatments on days to 50 per cent flowering and siliqua initiation of Indian mustard was found to be non-significant.

Yield and yield attributes:-

Using 125% of recommended fertilizers + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively recorded significantly higher economic yield, biological yield (kg ha^{-1}) and harvest index (%) than the other treatments except foliar spray of glyphosate at 25 and 50g ha^{-1}+1% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively.

Quality studies:

Oil content and oil yield were maximum with application of 125% of recommended fertilizer + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively.

Phyto-toxicity of different treatments on mustard:

No phyto-toxicity in Indian mustard was observed due to any of the treatments at 40DAS. But, at 65DAS, *Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 25 and 50 g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively and *Neem* cake 400kg ha^{-1} at sowing followed by foliar spray of glyphosate at 20 and 40g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 45DAS, respectively caused some phytotoxicity to mustard crop.

Economics:

Using 125% of recommended fertilizers (N and P) + foliar spray of glyphosate at 25 and 50g ha^{-1} + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55DAS, respectively fetched maximum gross and net returns resulting in a B:C of 2.55 in comparison to 1.43 under weedy check and 1.16 when *Orobanche* shoots were pulled out manually thrice at 45, 65 and 85DAS.

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