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Growth, yield attributes, yield and quality as influenced by pre and post emergence herbicides in Indian mustard (*Brassica juncea* L.)

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Abstract

A field experiment was conducted at the Oilseed Agronomy Block of Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) during *rabi* season of 2020-21 to assess the performance of pre (Pendimethalin, Oxadiargyl, and Oxyfluorfen) and post emergence herbicides (Quizalofop and Fluazifop-p-butyl) in managing weeds in Indian mustard (*Brassica juncea* L.). The soil of the experimental area was silty clay loam in texture with a neutral pH (7.3), high in organic carbon (0.79 percent), available nitrogen is low (234 kg/ha), phosphorus is medium (21.6 kg/ha) and medium in potassium (216 kg/ha) contents. The experiment consisted of ten treatments were laid out in Randomized Block Design (RBD) with three replications. Indian mustard (variety PR-20) was sown at the geometry of 30cm×10cm. The results showed that the application of Quizalofop 5 EC 0.05 kg/ha (Early PoE) resulted in higher growth parameters (*viz.* plant height, plant dry matter and number of branches), yield attributes (*viz.* number of siliquae per plant, number of seeds per silique, seed weight per plant, length of silique), seed (2060 kg/ha), stover (5535kg/ha) and biological (7595kg/ha) yields, oil and protein contents, and oil (889kg/ha) and protein (528kg/ha) yields due to effective control of weeds. Higher net returns (61776Rs/ha) and benefit: cost ratio (2.81) were obtained with the application Quizalofop 5 EC 0.05 kg/ha (Early PoE).

Keywords: Pre-emergence, post-emergence, rapeseed-mustard, quizalofop, weed management, yield

Introduction

Oilseed's sector constitutes the second-largest agricultural economy of India in terms of area as well as production after cereals. India is the fourth-largest vegetable oil economy of the world after the US, China, and Brazil accounting for 12-15 per cent of the global oilseeds area, 6-7 per cent of the vegetable oils production, and 9-10 per cent of the total edible oil consumption. The important oilseed crops being rapeseed-mustard, soybean, and groundnut which contribute up to 88 percent in terms of area as well as production and more than 80 percent of the vegetable oil production (USDA, 2024-25). Rapeseed-mustard are grown in more than sixty countries. These are a primary source of edible oil. Being cultivated under a wide range of climatic conditions, the global area, production, and productivity of rapeseed-mustard are about 42.4 mha, 87.2 mt, and 1980 kg/ha, respectively (USDA, 2024-25). The area, production, and productivity of rapeseed-mustard in India is about 8.9 mha, 13.5 mt and 1419 kg/ha respectively (USDA, 2024-25).

Oilseeds *Brassica* comprises of eight several species such as Indian mustard (*Brassica juncea* L.), *Toria* (*Brassica rapa* L.), Yellow sarson (*Brassica rapa* L. sub sp. yellow sarson), Brown sarson (*Brassica rapa* sub sp. brown sarson), Gobhi sarson (*Brassica napus* L. spp. Spp. *Oleifera* var. *annua*), Karan rai (*Brassica carinata* L.), Black mustard (*Brassica nigra* L. Koch.) and Taramira (*Eruca sativa* (Miller)) which are commercially grown in India. Among the above species, Indian-mustard (*Brassica juncea* L.) is mainly grown in the states of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, Punjab, West Bengal, Gujarat, and Assam. It is also cultivated in the non-traditional regions of South India, such as Tamil Nadu, Andhra Pradesh, and Karnataka to some extent.

Technological improvement in mustard crop production has resulted in improved crop productivity, but several biotic stresses like weeds reduces crop yield up to 40-45 per cent in case of mustard crop, reducing the productivity of crop as well as quality parameters of crop by competing with mustard crop plants for available nutrients, moisture, light, and other resources, and influence the agro-ecosystem. As reported by Kalita *et al.*, 2017 [5] severe yield losses are caused by weeds (33 percent), insects (20 percent), pathogens (26 percent), storage pests (7 percent), rodents (6 percent) and others (8 percent) in India. Unlike the other oilseed crops, Indian mustard more vulnerable to weed competition at the early stage of crop growth period particularly between 20-40 DAS, which is the critical stage of crop weed competition for mustard crop (DRMR, 2012). Later on, the crop expands its branches and smothers the weeds growth. Therefore, at later stages of the crop itself becomes competitive, so management of weeds at the critical stage of crop growth can provide the best results.

The weeds are managed by mechanically, agronomically, biologically, and through chemically; and, by including more than one method of weed control is called integrated weed management (IWM). In mustard, the weeds are managed by physical method (1-2 hand weeding's) and chemical method (use of pre-and post-emergence herbicides). The manual and mechanical approaches are most expensive, time consuming and labour intensive of all. Various dinitroaniline herbicides are mostly used to control weeds and most of these herbicides are effective against only a narrow range of weed species. It is reported that either fluchloralin or pendimethalin single or in integration with hand-weeding at 30 DAS was the most cost-effective in managing weeds of rapeseed & mustard. Similar conclusion has been also reported by Rath *et al* (2005) [11].

Materials and Methods

A field experiment was carried out at the Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pant Nagar, district Udham Singh Nagar, Uttarakhand, representing the *tarai* belt of Uttarakhand, in 2020-21 during the *rabi* season. Pant Nagar is located in the Himalayan foothills at 29°N latitude, 79.3°E longitude, and altitude of 243.83°m above mean sea level. The soil of experimental plot was silty clay loam, slight alkaline (pH 7.3) in nature and low to medium fertile being medium to high in organic carbon (0.79 percent) and low in available nitrogen (234 kg/ha), medium in available phosphorus (21.6kg/ha) and available potassium is also in a medium range (216 kg/ha).

The experiment consisted of ten treatments (Table 1) were laid out in Randomized Block Design (RBD) with three replications. PR-20 variety of Indian mustard was grown with the geometry of 30cm at a seed rate of 5.0 kg/ha on the last week of October. All the herbicides were applied in the form of an aqueous solution containing 550 litres of water per hectare with the assistance of a knapsack sprayer. Pendimethalin, Oxadiargyl, and Oxyfluorfen were applied within 1 or 2 days after sowing as pre-emergence whereas Quizalofop, and Fluzifop-p-butyl were applied at 17 and 32 DAS, respectively. A recommended dose of nitrogen (120kg/ha), phosphorus (40kg/ha), and potassium(20kg/ha) were applied through Urea, Single superphosphate, and Muriate of potash, respectively. At the time of sowing, a full dose of potash and phosphorus and half amount of nitrogen were applied as basal dose. After the first irrigation, the half dose of nitrogen was applied as top dressing. The

requirement of sulphur was obtained from SSP. Thinning is an intercultural operation in which additional seedlings were manually thinned out after 20-25 days of sowing in each row to keep appropriate plant to plant distance (10 cm).

Observation on plant height (cm), plant dry matter (g/plant) and number of branches per plant were recorded at 30, 60, 90 DAS and harvest. At harvest, siliquae per plant, length of siliquae, number of seeds per silique, seed weight per plant and 1000-seed weight were recorded. After drying in sun, the crop was threshed, cleaned, weighed, and the seed yield was recorded in kilograms per plot, which was then converted to kilograms per hectare by using the conversion factor. Stover yield of crop was calculated by deducting the seed yield from the total dry weight of the bundle from each plot and was expressed in kg/ha. After harvesting the produce (seed and stover) from the base with the help of sickle, it was bundled, labelled, and dried in sun. To calculate biological yield, bundles were weighed using a handheld balance before threshing. The oil and protein yield, which is expressed in kg/ha, was computed by multiplying the value of the oil and protein content by the seed yield as determined by the treatment. The oil content of the seeds was determined by using a non-destructive method. It was determined by using FT-NIR (Near-infrared spectroscopy) method. The oil content was expressed as a percentage. By using formula, the protein content of the seeds was determined by multiplying their nitrogen content.

Results and Discussion

Growth studies

Plant height

Generally, plant height increased with the increment of crop growth, and the maximum plant height were observed at harvest. The maximum plant height of Indian mustard was observed under weed-free conditions during the entire crop growth duration. Among the various herbicides, the application of Quizalofop 5 EC 0.05 kg/ha (Early PoE) resulted in the tallest plants, which was significantly superior over that obtained with application of Oxadiargyl 6 EC 0.045 kg/ha (P.E.) and Fluzifop-p-butyl 13.4 EC 0.125 kg/ha (PoE) at 30 DAS. At 60 DAS, the tallest plant observed with the application of Quizalofop 5 EC 0.05 kg/ha (Early PoE), which was significantly superior than both of Oxadiargyl 6 EC 0.09 and 0.045 kg/ha (P.E.) as well as Oxyfluorfen 23.5 EC 0.15 kg/ha (P.E.) applied plots. At 90 DAS, Quizalofop 5 EC 0.05 kg/ha (Early PoE) treated plots further resulted in the maximum plant height, while the differences among the herbicide treatments was remained statistically on a par except Oxadiargyl 6 EC 0.045 kg/ha (P.E.) and Oxyfluorfen 23.5 EC 0.15 kg/ha (P.E.) applied plots. At maturity, however, the differences among most of the herbicides and their application rates remained statistically on a par though tallest plants were still produced with Quizalofop 5 EC 0.05 kg/ha at 17 DAS applied plots. The weedy check ended up with smallest plant during entire crop growth period. The height of plants is the indication of healthy and vigorous crop growth. It is associated with the strong root system and accessibility of nutrients to the crop, which further leads to development and elongation of plant cell (Hussain *et al.*, 2013) [3]. Due to application of Quizalofop 5 EC 0.05 kg/ha at 17 DAS and Pendimethalin 30 EC 1.0 kg/ha (P.E.), weeds were controlled effectively due poor crop-weed competition at the early stage of crop growth and plants was able to utilise resources effectively for plant growth.

Dry matter accumulation

Plant dry matter was recorded at 30, 60, 90 DAS, and at harvest. The plant dry matter was significantly affected by various treatments. The maximum plant dry matter was accumulated in case of weed free conditions during all stages of crop growth. At 30 DAS, among the various herbicide treated plots, the application of Quizalofop 5 EC 0.05 kg/ha at 17 DAS observed the highest plant dry matter which was significantly superior over other herbicide treated plots except for Pendimethalin 30 EC 1.0 kg/ha as pre-emergence, Pendimethalin 30 EC 0.5 kg/ha (P.E.) which did not differ significantly in terms of dry weight of plant. At 60 days after sowing, too significantly maximum dry matter was accumulated with Quizalofop 5 EC 0.05 kg/ha (Early PoE) and it continued to remain maximum subsequently at 90 days after sowing and at harvest. However, at 90 days after sowing and harvest stage, the application of Pendimethalin 30 EC 1.0 kg/ha as pre-emergence remained statistically at par with Quizalofop 5 EC 0.05 kg/ha at 17 DAS applied plots. The lowest plant dry matter was recorded in case of the control plot (the weedy check) by being significantly low in comparison with almost all the other treatments. Accumulation of dry matter may be due to the decreased total weed density and soil moisture, sunlight, nutrients, and other resources for the crop, accumulating more dry matter with Quizalofop 5 EC 0.05 kg/ha (Early PoE) applied plots.

Yield attributes

Number of branches per plant

Among the herbicide treated plots, Quizalofop 5 EC 0.05 kg/ha applied at 17 DAS bore the maximum number of primary branches which was significantly superior over the other treatments except Pendimethalin 30 EC 1.0kg/ha as pre-emergence and Fluazifop-p-butyl 13.4 EC 0.125 kg/ha (PoE) which produced a statistically comparable number of branches/plant to that of Quizalofop 5 EC 0.05 kg/ha at 17 DAS treated plots. In case of secondary branches, Quizalofop 5 EC 0.05 kg/ha at 17 DAS treated plots excelled again producing the highest number of secondary branches, which was considerably superior over the other herbicides except Pendimethalin 30 EC 1.0 kg/ha (PE) which did not differ significantly. Quizalofop 5 EC 0.05 kg/ha at 17 DAS recorded the maximum number of tertiary branches. It was followed by Pendimethalin 30 EC 1.0 kg/ha as pre-emergence. Mankar (2015) from Nagpur noted that post-emergence application of Quizalofop produced statistically a greater number of total branches per plant. The number of branches in Indian mustard is affected by temperature, moisture, nutrients, space, and other resources. As herbicides decreased the total weed density, resulting in maximum absorption and assimilation of the supplied nutrients, moisture, and other resources by the crop plants, those plants produced copious branching.

Number of siliquae per plant

The application of Quizalofop 5 EC 0.05 kg/ha at 17 DAS resulted in the highest number of siliquae per plant which remained significantly superior to all other herbicidal treatments except Pendimethalin 30 EC 1.0 kg/ha as pre-emergence and Fluazifop-p-butyl 13.4 EC 0.125 kg/ha (PoE), which did not differ significantly. Similar results also founded by Mundra and Maliwal (2012)^[8] and Patel *et al.* (2013)^[9]. Siliquae per plant is influenced by flowering in Indian mustard more or less depend on temperature but then again number of flowers per plant is also influenced by number branching per plant. Therefore,

maximum number of plant branches leads to vigorous flowering which resulting a greater number of siliquae per plant.

Length of siliquae

The various herbicides and their rates of application significantly affect the length of siliqua. Among the various herbicide treated plots, Quizalofop 5 EC 0.05 kg/ha at 17 DAS recorded highest length of siliqua, which remained statistically at par with Pendimethalin 30 EC 1.0kg/ha (P.E.), Fluazifop-p-butyl 13.4 EC 0.125 kg/ha (PoE), and Pendimethalin 30 EC 0.5 kg/ha (P.E.) applied plots. More siliqua length might be due to adequate translocation of photosynthates towards the sink due to a decreased competition by weeds in Quizalofop applied plots.

Number of seeds per siliquae

It was revealed that, Quizalofop 5 EC 0.05 kg/ha treated plots resulted in highest number of seeds per siliqua, which was statistically better than the other herbicide treated plots. Similar findings were also founded by Bharat *et al.* (2015)^[2]. More seeds per siliqua may be due to better reproductive growth and effective photosynthetic translocation along with the length of siliqua also influenced the number of seeds per siliqua.

1000- seed weight

The highest value of test weight was recorded with application of Quizalofop 5 EC 0.05 kg/ha (Early PoE) and which was followed by Pendimethalin 30 EC 1.0 kg/ha (P.E.), Fluazifop-p-butyl 13.4 EC 0.125 kg/ha (PoE), Pendimethalin 30 EC 0.5 kg/ha (P.E.) and Oxyfluorfen 23.5 EC 0.3 kg/ha (P.E.), which is also confirmed by Kachroo and Bazaya (2006)^[4]. The weight of 1000- seeds generally influenced by varietal characters. However, to some extent the variation here could also be due to more dry matter accumulation as well as better crop conditions owing to lower weed population that resulted in better accumulation of photosynthates to the sink (*i.e.*, seed) in properly managed plots.

Seed weight per plant

The application of Quizalofop 5 EC 0.05 kg/ha (Early PoE) recorded more seed weight per plant, which was statistically better than the other herbicide treated plots except Pendimethalin 30 EC 1.0 kg/ha (P.E.), which did not differ significantly in terms of seed weight per plant. Similar findings also documented by Bharat *et al.* (2015)^[2]. Least seed weight per plant was observed in control (the weedy check) plot. Higher seed weight per plant attributed to lower weed density facilitates less crop-weed competition for soil moisture, available nutrients, sunlight, and space resulting in more yield attributing characters and those characters contribute to more seeds per plant.

Yield

Quizalofop 5 EC 0.05 kg/ha (Early PoE) treated plots resulted in maximum seed yield which was significantly superior over that of the other herbicides and their application rates except Pendimethalin 30 EC 1.0 kg/ha (P.E.) which did not differ significantly in terms of seed yield. These findings were also supported by Rana (2015)^[10], Mathukia *et al.* (2015)^[7], Singh *et al.* (2014)^[12] and Bharat *et al.* (2015)^[2]. The higher yield of seeds was the resultant of the higher values for growth parameters (*viz.* total dry matter accumulation and number of branches per plant), yield attributing parameters (*viz.* siliquae per plant, seeds per siliqua, and seed weight per plant) and low density of weeds. Proper translocation and accumulation of

photosynthates led to better growth parameters and yield attributing characters which finally made up the higher seed

yield with application of Quizalofop 5 EC 0.05 kg/ha at 15-20 DAS. The application of Quizalofop 5 EC 0.05 kg/ha (Early PoE) recorded in higher stover yield being significantly superior over that of the Oxadiargyl 6 EC 0.045 kg/ha (P.E.). The other herbicide applied plots, however, did not differ significantly. This is in line with the finding of Kachroo and Bazaya (2006) [4]. Higher stover yield might be due to effective control of weeds at the early stage of crop growth which resulted in better availability of soil moisture and nutrients to the crop leading to a greater dry matter accumulation. Application of Quizalofop 5 EC 0.05 kg/ha (Early PoE) also resulted in maximum biological yield. These results are in conformity with Rana (2015) [10]. Higher biological yield might be attributed to the collective effects of seed and stover yields. The reduced weed density resulted in poor competition between plants and weeds leading to proper availability of plant nutrients, moisture, light, and space and it could facilitate better translocation of photosynthates and higher dry matter accumulation finally resulting in higher economic, stover as well as biological yields.

Quality parameters

The oil and protein content of seeds in Indian mustard did not vary significantly among the herbicide treatments. However, Quizalofop 5 EC 0.05 kg/ha (Early PoE) applied plots analysed the highest oil and protein content among all the herbicides treated plots. The highest oil yield and protein yield resulted with the application of Quizalofop 5 EC 0.05 kg/ha (Early PoE). Yield of oil is the result of oil content in seed multiplied by the seed yield/ha. Therefore, higher the oil content, and seed yield resulting in higher oil yield. In case protein content in seeds depends on adequate assimilation of nutrients particularly nitrogen. Because of poor crop- weed competition, most of the nutrients are easily accessible to the plants, which leads to higher protein content, therefore higher protein yield obtained.

Table 1: Plant height and Plant dry matter accumulation of Indian mustard as influenced by the application of various herbicide treatments.

Treatment	Plant height (cm)				Plant dry matter accumulation (g/plant)			
	30 DAS	60 DAS	90 DAS	Maturity	30 DAS	60 DAS	90 DAS	Maturity
Pendimethalin 30 EC 1.0 kg/ha (P.E.)	38.5	100.1	142.0	161.4	5.8	12.3	33.3	34.4
Pendimethalin 30 EC 0.5 kg/ha (P.E.)	36.1	95.9	134.4	156.9	5.7	10.9	30.6	30.8
Oxadiargyl 6 EC 0.09 kg/ha (P.E.)	34.0	94.9	132.6	153.6	4.3	8.8	28.3	29.1
Oxadiargyl 6 EC 0.045 kg/ha (P.E.)	32.5	87.9	130.5	148.7	3.4	7.1	22.3	26.8
Fluazifop-p-butyl 13.4 EC 0.125 kg/ha (PoE)	30.7	97.5	137.3	158.1	3.1	12.0	31.3	32.2
Quizalofop 5 EC 0.05 kg/ha (Early PoE)	40.3	112.5	148.2	170.5	6.8	14.8	36.3	37.8
Oxyfluorfen 23.5 EC 0.3 kg/ha (P.E.)	35.6	95.3	133.1	155.6	4.7	9.2	30.3	30.0
Oxyfluorfen 23.5 EC 0.15 kg/ha (P.E.)	33.0	92.2	130.5	152.5	3.6	7.8	26.7	28.6
Control (the weedy check)	30.4	74.8	125.5	142.0	3.2	6.3	20.9	24.7
Weed- free	42.4	117.0	158.5	178.4	7.5	15.3	40.7	45.1
SEm±	2.6	5.8	5.6	6.6	0.4	0.8	1.7	1.7
CD(P=0.05)	7.7	17.3	16.5	19.5	1.2	2.4	5.0	5.1

Table 2: Yield attributes in Indian mustard at harvest as influenced by the application of various herbicide treatments.

Treatment	Primary branches	Secondary branches	Tertiary branches	No. of siliquae/plant	Length of siliqua (cm)	No. of seeds/siliqua	Seed weight/plant (g)	1000 Seed weight (g)
Pendimethalin 30 EC 1.0 kg/ha (P.E.)	6.7	9.7	3.1	189.4	4.2	12.3	11.1	4.75
Pendimethalin 30 EC 0.5 kg/ha (P.E.)	5.5	7.6	2.3	168.8	3.9	11.5	9.6	4.64
Oxadiargyl 6 EC 0.09 kg/ha (P.E.)	5.0	6.8	2.1	143.3	3.6	9.6	9.2	4.53
Oxadiargyl 6 EC 0.045 kg/ha (P.E.)	4.6	6.0	2.0	136.5	3.2	8.9	8.2	4.42
Fluazifop-p-butyl 13.4 EC 0.125 kg/ha (PoE)	6.4	8.1	2.6	178.3	4.0	11.6	9.8	4.68
Quizalofop 5 EC 0.05 kg/ha (Early PoE)	7.3	11.2	4.6	210.1	4.3	13.3	12.1	4.79
Oxyfluorfen 23.5 EC 0.3 kg/ha (P.E.)	5.2	7.4	2.2	150.8	3.7	9.8	9.4	4.55
Oxyfluorfen 23.5 EC 0.15 kg/ha (P.E.)	4.8	6.4	2.0	139.3	3.4	9.2	8.6	4.46
Control (the weedy check)	3.3	3.6	1.4	123.9	2.9	8.0	7.3	4.23
Weed- free	8.3	14.2	5.3	228.9	4.5	14.5	13.6	4.83

S.Em±	0.3	0.7	0.1	13.9	0.2	0.9	0.7	0.19
CD(P=0.05)	1.0	2.1	0.4	41.2	0.5	2.6	2.0	NS

Table 3: Effect of various herbicide treatments on the yields and quality parameters of Indian mustard.

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)	Protein content (%)	Protein yield (kg/ha)
Pendimethalin 30 EC 1.0 kg/ha (P.E.)	1994	5431	7425	42.9	854	24.5	491
Pendimethalin 30 EC 0.5 kg/ha (P.E.)	1754	4917	6671	42.2	741	23.8	418
Oxadiargyl 6 EC 0.09 kg/ha (P.E.)	1667	4774	6441	41.5	695	23.4	391
Oxadiargyl 6 EC 0.045 kg/ha (P.E.)	1490	4520	6010	41.2	614	23.2	346
Fluazifop-p-butyl 13.4 EC 0.125 kg/ha (PoE)	1767	4918	6684	42.5	748	24.3	427
Quizalofop 5 EC 0.05 kg/ha (Early PoE)	2060	5535	7595	43.1	889	25.6	528
Oxyfluorfen 23.5 EC 0.3 kg/ha (P.E.)	1688	4802	6490	41.5	700	23.6	399
Oxyfluorfen 23.5 EC 0.15 kg/ha (P.E.)	1564	4621	6185	41.3	646	23.1	361
Control (the weedy check)	1046	3337	4383	40.5	549	22.7	307
Weed- free	2143	5689	7832	43.6	933	26.1	560
S.Em±	93.5	310.2	287.8	1.4	51.4	1.0	34.3
CD (P=0.05)	278	922	855	NS	153	NS	102

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