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Effect of phosphorous and growth regulators on Gobhi Sarson (*Brassica napus*)

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Abstract

A field experiment was conducted at Research farm, Department of Agronomy, Lovely Professional University Phagwara, during rabi season of 2020-21 to study the effect of phosphorous and growth regulators on Gobhi Sarson (*Brassica napus*). The experiment was laid out in Factorial Randomized Block design with 12 treatments and 3 replications. The experiment consisted of four phosphorous levels i.e., 0, 15, 30 and 45 kg P_2O_5 ha^{-1} without and with growth regulators i.e., Salicylic acid at 100 ppm and Naphthalene acetic acid at 40 ppm at 60 and 80 DAS. Application of 45kg P_2O_5 ha^{-1} + NAA 40 ppm significantly improved growth parameters *viz*. plant height, chlorophyll content, leaf area index, dry matter accumulation, Crop growth rate, relative growth rate at 90 DAS and number of primary and secondary branches per plant at the time of harvest. Similar trend as that of growth parameters where also observed in yield parameters *viz*. number of siliquae $plant^{-1}$, number of seeds $siliquae^{-1}$, siliquae length (cm) and seed yield (t ha^{-1}) due to application of 45kg P_2O_5 ha^{-1} + NAA 40 ppm at the time of harvest.

Keywords: Gobhi Sarson, phosphorous, growth regulators, yield, oil content, phosphorous uptake

Introduction

India has the world's fourth-largest oilseed economy. Among the seven edible oilseeds cultivated in India, rapeseed-mustard accounts for 28.6% of total oilseed production, and rapeseed and mustard is India's most important *rabi* oilseed crop, accounting for 27.8% of the country's oilseed economy. The scientific name for gobhi sarson is (*Brassica napus*). Gobhi sarson is a long-duration crop (155 days) found only in Punjab, Himachal Pradesh, and Haryana. The states of Rajasthan, Uttar Pradesh, Haryana, Punjab, Madhya Pradesh, and Gujarat are the largest producers of mustard in India. Rajasthan has the most rapeseed and mustard area and production, with 2.50 million hectares and 4.08 million tonnes (2017) respectively (Anonymous, 2017) [1].

The quality of the oil in rapeseeds and mustard contains a sufficient amount of erucic acid (40-60%), as well as linolenic acid (4.5-13%). Just about 25- 30 percent of the nutrition is oleic acid and linoleic acid, which have a higher nutritive value (Gautam, *et al*., 2020) [7]. Calcium, manganese, copper, iron, selenium, zinc, vitamin A, B, C, and proteins are all abundant in mustard. Mustard seed has 508 calories per 100 grams, 28.1 grams of carbohydrates, 26.1 grams of protein, 25-35 percent total fat, and 12.2 grams of dietary fiber (Anonymous, 2016) [2]. The oil content in mustard is about 35-40% and protein content ranges from 25-30%.

Phosphorus is important for improving and maintaining crop productivity all over the world. Brassica species have a high phosphorus requirement, according to common perception. Many soils have a significant amount of this nutrient, but not enough to meet the needs of the rapeseed and mustard crop due to low temperature during initial growth period the residual P availability is low. Phosphorus fertilizer has impact on yield, even less than Nitrogen, but noticeably more than Potassium. Phosphorus is an essential component of plant metabolism since it aids in cellular energy transfer, respiration, and photosynthesis. It increases oil content, seed size, and stimulates seed filling. As a component of nucleoproteins and nucleotides, it participates in metabolic activities and is involved in the formation of energy-rich bonds such as adenosine diphosphate (ADP) and adenosine triphosphate (ATP) (Solanki *et al*., 2016) [23]. Phosphorus is generally deficient in the majority of our Indian soils and needs much attention for maintenance of soil fertility. sufficient P gets a hard start right from the seedling stage, produces deeper and proliferous roots which enable it to feed on a bigger soil volume for water and nutrients.

Plant hormones are developed naturally by the plants and are essential for their growth regulation. When applied as a foliar spray at the proper crop growth stage in optimum

Concentration, PGRs that boost plant physiological efficiencies could play a significant role in increasing crop yield and quality (Garai and Datta, 2003) [8]. Salicylic acid (SA) is a phenolic phytohormone that plays a role in plant growth and development, photosynthesis, transpiration, ion uptake, and transport, among other things. SA, a powerful signalling molecule in plants, plays a role in defensive mechanisms by controlling physiological and biochemical functions, as well as having a variety of effects on biotic and abiotic stress tolerance (Muthulakshmi and Lingakumar, 2017) [14]. Naphthalene acetic acid (NAA) is a commonly used synthetic auxin in plants. Auxin encourages cell elongation, or expansion, at low concentrations, but inhibits growth at higher concentrations (Chute *et al*., 2017) [4]. Auxins affect plants and their other growth regulators in a number of ways. Different plants have shown different effects of NAA application in terms of rooting speed, flower power, fruit setting ratio, fruit drop prevention, and fruit formation (Prakash and Ganesan, 2001) [19].

Materials and Methods

A field experiment was conducted during winter (rabi) season of 2020-21 at Lovely Professional University Phagwara Research Farm, which is located at 31º 15'N, 75º 42' E, and 235 m above mean sea level in Punjab. The variety of rapeseed-mustard was HYOLA PAC 401. The recommended dose of fertilizer 100:30:0 kg /ha (N:P:K) in the form of Urea, DAP was applied to the soil as 50% N and 100% P basal dose and the remaining 50% N applied at 30 DAS. The land is ploughed 2 times to make free from weeds, clods after ploughing land are leveled 26 November 2020. The sowing was done on 27th, Nov 2020 line sowing was done with row to row spacing of 30cm and depth is 3-5 cm. The irrigation was given whenever necessary. The recommended cultural operations and plant protection measures were carried out timely. The foliar sprays of PGR's Salicylic acid 100 ppm and Naphthalene acetic acid 40 ppm were given at the time of 60 and 80 DAS. The experiment was laid out in a Factorial Randomized Block design with three replications having plot size 5 x 3 m^2. Twelve treatment combinations comprising T1 @ 0 P kg ha^{-1} + 0 GR, T2 @ 15 P kg ha^{-1} + 0 GR, T3 @ 30 P kg ha^{-1} + 0 GR, T4 @ 45 P kg ha^{-1} + 0 GR, T5 @ 0 P kg ha^{-1} + SA 100 ppm, T6 @ 15 P kg ha^{-1} + SA 100 ppm, T7 @ 30 P kg ha^{-1} + SA 100 ppm, T8 @ 45 P kg ha^{-1} + SA 100 ppm, T9 @ 0 P kg ha^{-1} + NAA 40 ppm, T10 @ 15 P kg ha^{-1} + NAA 40 ppm, T11 @ 30 P kg ha^{-1} + NAA 40 ppm, T12 @45 P kg ha^{-1} + NAA 40 ppm.

The soil at the experimental site was loamy sand- clay % 4.08, silt % 11.22, and sand % 84.7, neutral in pH of 7.2 and EC =1.07 ds/m with an initial fertility status of medium-range in available Nitrogen 295 kg ha^{-1}, low range in available phosphorous 18.46 kg ha^{-1} P2O5, medium-range in available potassium 180 kg ha^{-1} K, low range in organic carbon is 0.285% and finally, organic matter is 0.491%.

soil texture determined by mechanical analysis using the pipette method, pH of the soil was determined with the help of digital pH meter, EC of soil is analysed with an electrical conductivity meter (Jackson, 1967), Organic carbon was determined by Walkley and Black's titration method, Available Nitrogen estimated by Kjeldhal's procedure (Subbiah and Asija 1956), Available Phosphorous estimated by Olsen's method (Olsen *et al*. 1954), Available Potassium estimated by Flame Photometer (Toth and Prince 1949).

The observations were recorded as per the 5 plants were selected randomly in each net plot. Plant growth parameters like plant height, chlorophyll content, leaf area index, dry matter accumulation, crop growth rate, relative growth rate, primary branches, secondary branches and yield parameters like number of siliquae per plant, length of siliquae, number of seeds per siliquae, and seed yield.

Crop growth rate: CGR was calculated using the below formulae.

CGR= $(W2-W1)/t_2-t_1$ g m^2 day^1

Relative growth rate: RGR was calculated using the below formulae.

RGR= $(\log_e W_2-\log_e W_1)/t_2-t_1$

Result and Discussion

1. Plant height

The data Indicates that plant height at different growth stages 30,60 and 90DAS is given in table 1.a. At 30 and 60 DAS application of growth regulators had no significant effect on plant height. At 90 DAS application of growth regulators had significant effect on plant height. The maximum plant height was observed in application of NAA 40 ppm (133.5 cm) and lowest in without growth regulator (126.1 cm) was recorded. At 90 DAS, application of NAA 40 ppm increased plant height to the magnitude of 5.87% when compared to without growth regulator. The application of phosphorous levels had no significant effect on plant height at 30 DAS. At 60 and 90 DAS application of phosphorous levels had significant effect on plant height. The maximum plant height was observed in 45 kg P_2O_5/ha i.e., (23.2 and 136.56 cm) and lowest in 0 kg P_2O_5/ha i.e., (20.0 and 124.11 cm) was founded. At 60 & 90 DAS, application of 45kg P_2O_5/ha increased plant height by a tune of 16, 10.0% when compared to control (0 kg P_2O_5/ha). The interaction application of growth regulators and phosphorous levels had no significant effect on plant height at 30, 60 and 90 cm DAS. Application of NAA 100ppm enhanced the plant height in mustard (Kumar *et al*., 2018) [10]. And also the application of phosphorous influenced the growth attributes like plant height in mustard (Potdar *et al*., 2019) [18].

2. Chlorophyll content

The data pertaining to chlorophyll at different growth stages 30, 60 and 90DAS have been presented in table 1.b. At 30 and 60 DAS application of growth regulators had no significant effect on chlorophyll. At 90 DAS application of growth regulators had significant effect on chlorophyll. The maximum chlorophyll content was noted in application of NAA 40 ppm (58.6) and lowest in without growth regulator (46.0) was observed. At 90 DAS, Application of NAA 40 ppm increases chlorophyll content to the magnitude of 27.4% when compared to without growth regulator. The increasing level of phosphorous had no significant effect on chlorophyll content at 30 DAS. At 60 and 90 DAS application of phosphorous had significant effect on chlorophyll content. The higher chlorophyll content was recorded in 45 kg P_2O_5/ha i.e., (53.7 and 57.1) and lowest in 0 kg P_2O_5/ha i.e., (49.9 and 50.3) was recorded. At 90 DAS, application of 45kg P_2O_5/ha increased chlorophyll content by a tune of 7.6 & 13.5% over control (0 kg P_2O_5/ha). The interaction of growth regulators and phosphorous levels had no significant effect on chlorophyll content at 30, 60 and 90 DAS. Application of growth regulator SA 0.5 mM significantly influenced the total chlorophyll content in mustard (Sharma *et al*., 2017) [27]. According to (Haridarshan *et al*., 2014) [9] effect of phosphorous levels influenced the chlorophyll content (SPAD values) in mustard.

Table 1: Effect of Phosphorous and growth regulators on plant height and chlorophyll content:

Treatments	Table 1.a. Plant height (cm)			Table 1.b. Chlorophyll content (SPAD value)		
	30 days	60 days	90 Days	30 days	60 days	90 days
Sources						
S1- without GR	10.7	21.6	126.1	44.1	51.8	46.0
S2- with GR (Salicylic Acid)	10.1	21.7	130.3	44.6	51.7	56.8
S3- with GR (Naphthalene Acetic Acid)	10.1	21.3	133.5	45.0	51.9	58.6
CD	NS	NS	3.96	NS	NS	1.60
SE	0.23	0.35	1.35	0.54	0.49	0.54
CV	7.72	5.67	3.60	4.22	3.29	3.50
Levels						
P1- 0 kg P_2O_5/ha	10.1	20.0	124.11	44.8	49.9	50.3
P2- 15 kg P_2O_5/ha	10.2	21.0	127.61	43.9	51.2	52.7
P3- 30 kg P_2O_5/ha	10.4	21.8	131.56	45.6	52.3	55.3
P4- 45 kg P_2O_5/ha	10.5	23.2	136.56	43.9	53.7	57.1
CD	NS	1.19	4.57	NS	1.67	1.84
SE	0.27	0.41	1.56	0.63	0.57	0.63
CV	7.72	5.67	3.60	4.22	3.29	3.50
Interaction (S*L)						
CD	NS	NS	NS	NS	NS	NS
SE	0.46	0.70	2.70	1.08	0.98	1.09
CV	7.72	5.67	3.60	4.22	3.29	3.50

3. Leaf area index

The data in respect to leaf area index at different stages of crop growth 30, 60, 90DAS have been presented in figure 1. (a.b.c.) At 30 and 60 DAS the application of growth regulators had no significant effect on leaf area index. Significantly maximum leaf area index at 90 DAS was obtained with the application of NAA 40 ppm (1.84) and lowest in without growth regulator (1.40) was founded. At 90 DAS, when compared to the without growth regulator, Application of NAA 40ppm increases LAI to the extent of 31.4% over without growth regulator. The different level of phosphorous had no significant effect on leaf area index at 30 DAS. At 60 and 90 DAS significantly maximum leaf area index with the application of 45 kg P_2O_5/ha i.e., (0.62 and 1.97), and lowest in 0 kg P_2O_5/ha i.e., (0.43 and 1.1) was founded. At 90 DAS, application of 45kg P_2O_5/ha increases LAI by a tune of 44.2 & 79.1% over control (0 kg P_2O_5/ha). The interaction effect of growth regulators and phosphorous levels had no significant effect on leaf area index at 30, 60 and 90 DAS. Effect of phosphorous levels influenced the leaf area index in mustard (Haridarshan *et al*., 2014) [9].

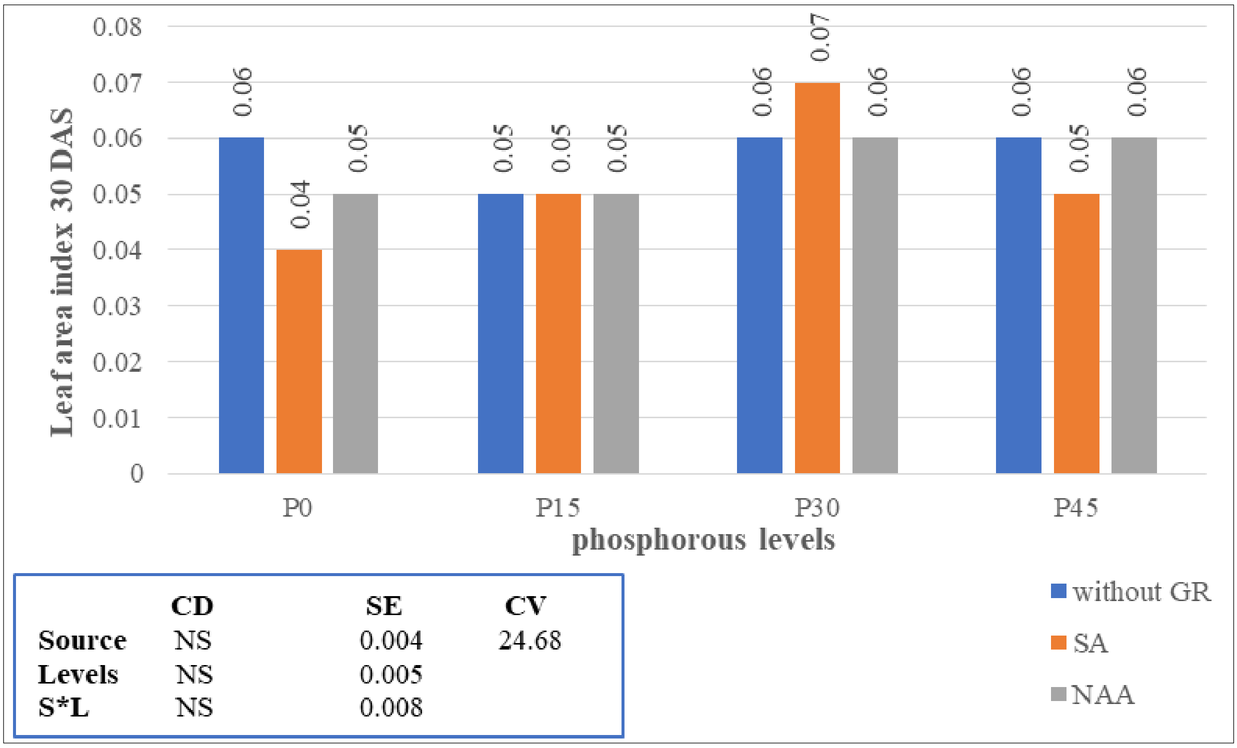

Fig 1.a: Effect of phosphorous and growth regulators on leaf area index at 30 DAS

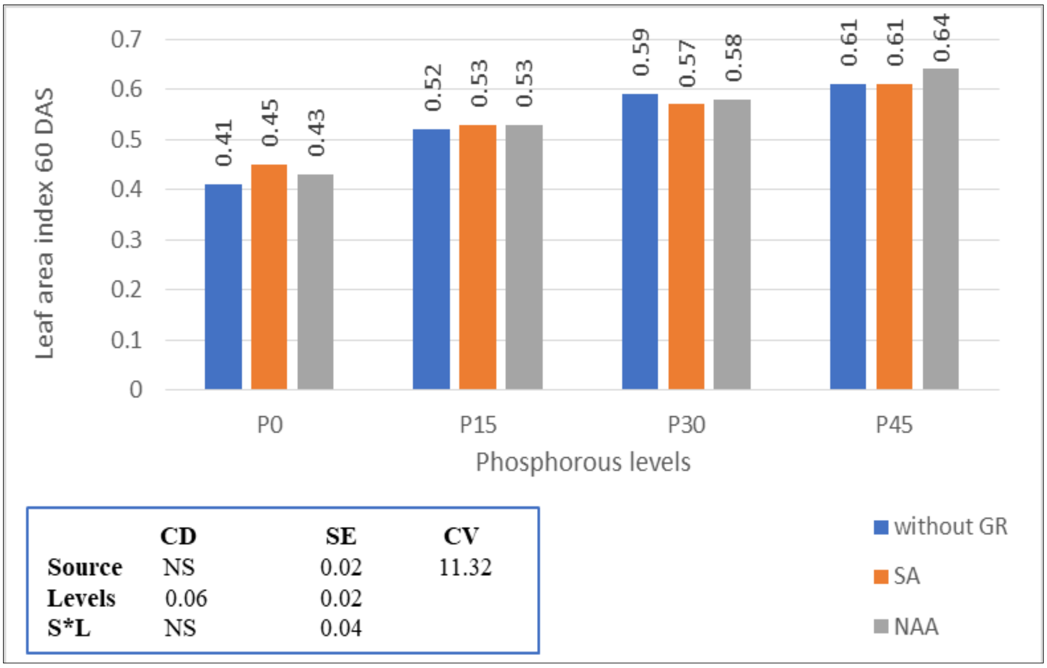

Fig 1.b: Effect of phosphorous and growth regulators on leaf area index at 60 DAS

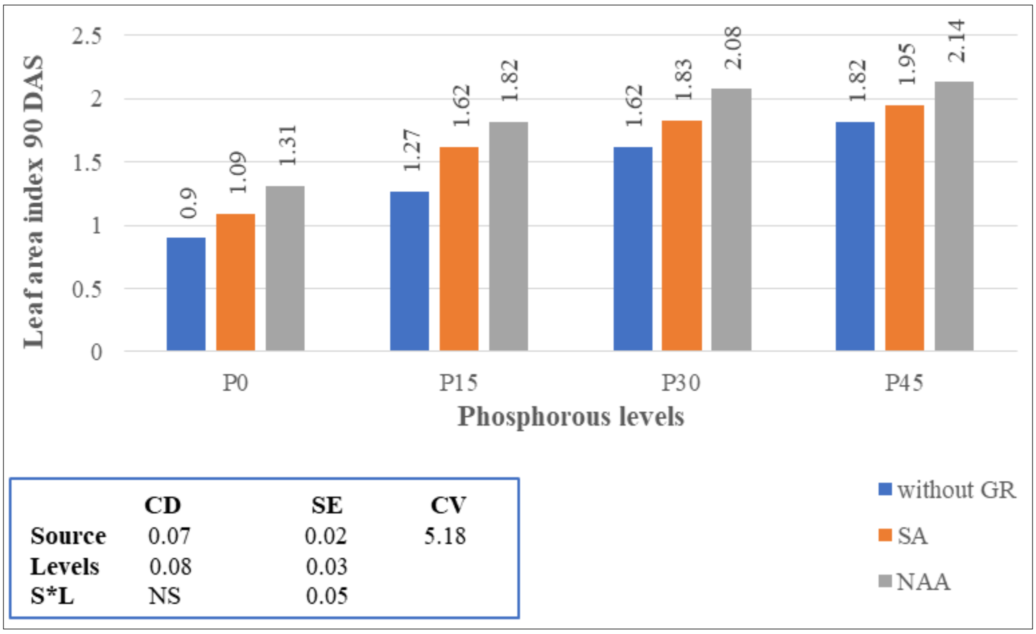

Fig 1.c: Effect of phosphorous and growth regulators on leaf area index at 90 DAS

4. Dry matter yield

The data Indicates that Dry matter accumulation at different growth stages is given in figure 2. (a.b.c.), At 30 and 60 DAS the application of growth regulators had no significant effect on dry matter. At 90 DAS the effect of growth regulators had significant effect on dry matter. Highest dry matter accumulation was obtained by the application of NAA 40ppm (6.16 t ha^{-1}) and lowest in without growth regulators (5.34 t ha^{-1}) was recorded. At 90 DAS, Application of NAA increases dry matter accumulation to the magnitude of 15.4% when compared to without growth regulator. A tendency of Significantly higher accumulation of dry matter was found at 30,60 and 90 DAS with increasing the phosphorous levels, presence maximum in application of 30 kg P_2O_5/ha at 30 DAS (0.09 t ha^{-1}) and lowest in 0 kg P_2O_5/ha (0.071 t ha^{-1}). At 30 DAS, application of 30 kg P_2O_5/ha increased dry matter by the tune of 26.8% over control (0 kg P_2O_5/ha). At 60 and 90 DAS highest dry matter accumulation was observed in 45 kg P_2O_5/ha i.e., (1.77 and 6.71 t ha^{-1}) and lowest in 0 kg P_2O_5/ha (1.38 and 4.95 t ha^{-1}) was recorded. At 60 & 90 DAS, application of 45 kg P_2O_5/ha increases dry matter to the magnitude of (28.3 & 35.5%) when compared to 0 kg P_2O_5/ha. The interaction effect of growth regulators and phosphorous levels had significant effect on dry matter accumulation at 30, 60 and 90 DAS. At 30 DAS, 30 kg P_2O_5/ha+ SA 100ppm was found higher dry matter (0.10 t ha^{-1}) followed by 45 kg P_2O_5/ha+ NAA 40ppm (0.093 t ha^{-1}) and, at 60 and 90 DAS significantly maximum dry matter accumulation with the application of 45 kg P_2O_5/ha+ NAA 40ppm i.e., (1.80 and 7.06 t ha^{-1}) followed by 45 kg + P_2O_5/ha SA 100 ppm (1.77 and 6.90 t ha^{-1}). Application of phosphorous influenced the dry matter accumulation in mustard (Potdar *et al.*, 2019) [18].

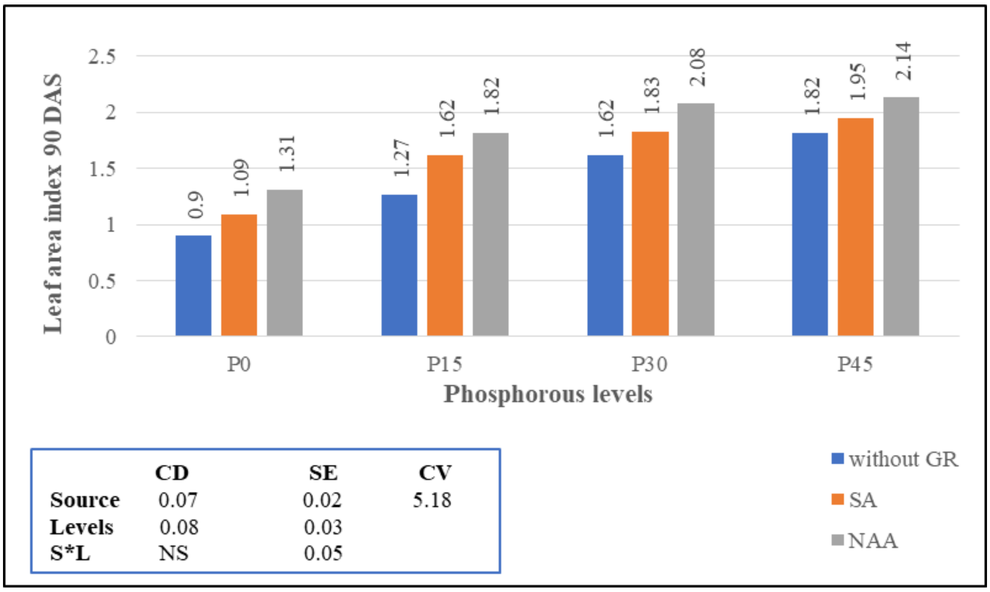

Fig 2.a: Effect of phosphorous and growth regulators on Dry matter (t/ha) at 30 DAS

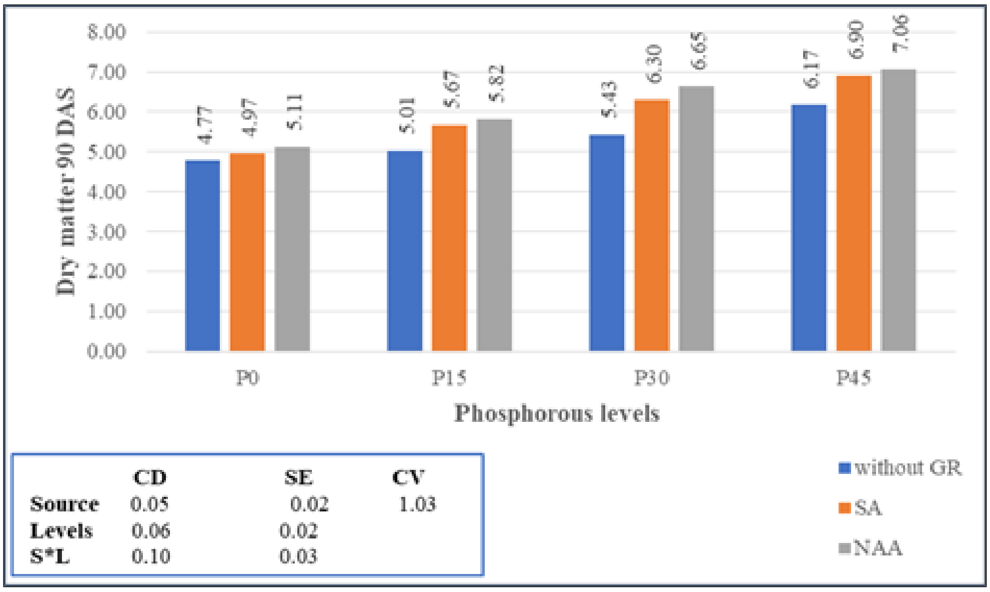

Fig 2.b: Effect of phosphorous and growth regulators on Dry matter (t/ha) at 60 DAS

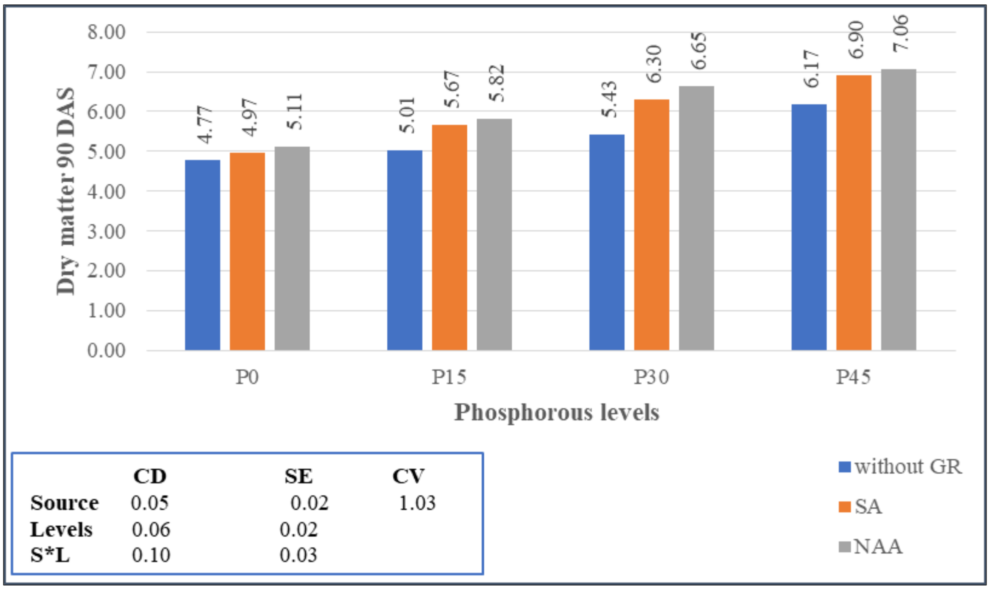

Fig 2.c: Effect of phosphorous and growth regulators on Dry matter (t/ha) at 90 DAS

5. Crop growth rate
The data revealed that crop growth rate at growth stages 30-60 and 60-90 DAS is has been presented in figure 3. (a.b). At 30-60 DAS the application of growth regulators had no significant effect on crop growth rate. At 60-90 DAS the effect of growth regulators had significant effect on crop growth rate. Highest CGR recorded by the application of NAA 40ppm (0.05) and lowest in without growth regulators (0.04) was recorded. At 90 DAS, application of NAA 40 ppm increased CGR to the magnitude of 25% compared to without growth regulator. The increasing levels of phosphorous had significant effect on crop growth rate at 30-60 and 60-90 DAS. The maximum CGR was obtained with the application of 45 kg P_2O_5/ha i.e., (0.019 and 0.054), lowest in 0 kg P_2O_5/ha i.e., (0.015 and 0.039) was recorded. At 30-60 & 60-90 DAS, application of 45 kg P_2O_5/ha increased CGR to the magnitude of (26.7 & 38.5%) when compared to 0 kg P_2O_5/ha. At 30-60 DAS, the interaction effect of growth regulators and phosphorous levels had no significant effect on crop growth rate. At 60-90 DAS interaction shows significant effect on crop growth rate. The application of 45 kg P_2O_5/ha+ NAA 40ppm shows highest CGR (0.058) followed by 45 kg P_2O_5/ha+ SA 100 ppm (0.056).

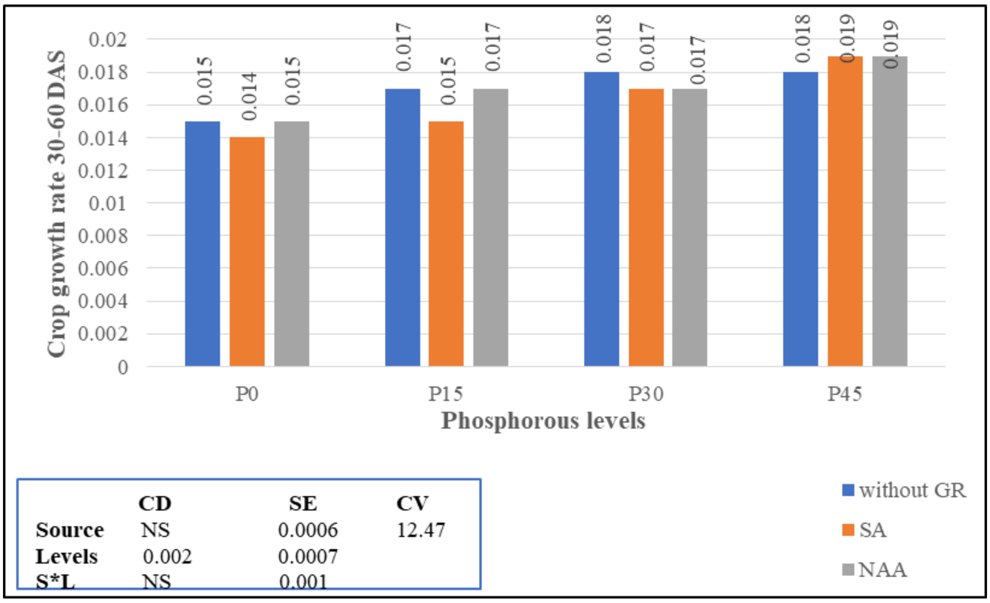

Fig 3.a. Effect of phosphorous and growth regulators on crop growth rate (g m⁻² day ⁻¹) 30-60 DAS

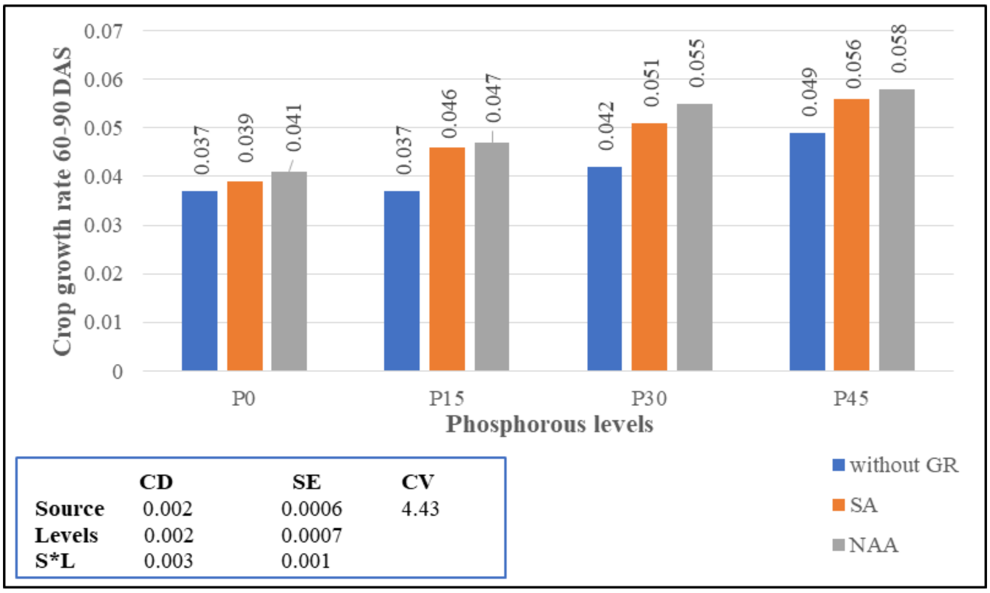

Fig 3.b: Effect of phosphorous and growth regulators on crop growth rate (g m^{-2} day $^{-1}$) at 60-90 DAS

6. Relative growth rate
The data pertaining to Relative growth rate at growth stages 30-60 and 60-90 DAS have been presented in figure 4. (a.b). At 60 DAS the application of growth regulators had no significant effect on relative growth rate. At 60-90 DAS the effect of growth regulators had significant effect on relative growth rate. maximum RGR was obtained by the application of NAA 40ppm and also SA 100 ppm found (0.093) and lowest in without growth regulators (0.091) was founded. At 60-90 DAS, application of SA 100 PPM, NAA 40 ppm increased the RGR to the magnitude of 2.2% compared to without growth regulator. The increasing levels of phosphorous had significant effect on relative growth rate at 30-60 and 60-90 DAS. The maximum RGR was obtained with the application of 45 kg P_2O_5/ha i.e., (0.075 and 0.094), lowest in 0 kg P_2O_5/ha i.e., (0.071 and 0.090) was founded. At 30-60 & 60-90 DAS,

application of 45 kg P_2O_5/ha increased RGR by a tune of 5.6 & 4.4% when compared to control (0 kg P_2O_5/ha). The interaction effect of growth regulators and phosphorous levels had no significant effect on relative growth rate at 30-60 and 60-90 DAS.

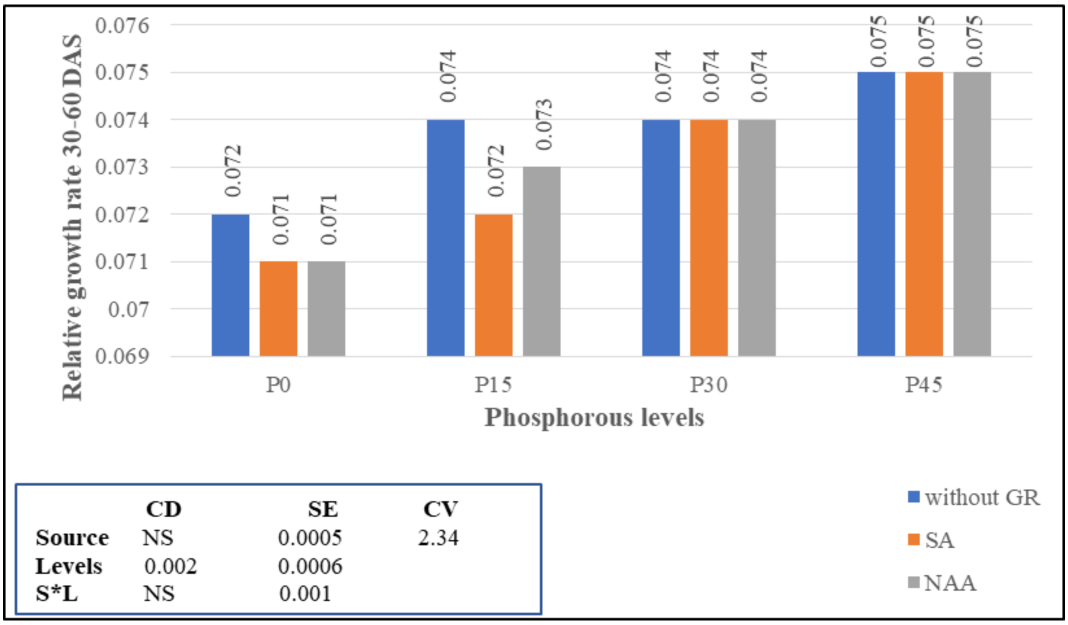

Fig 4.a: Effect of phosphorous and growth regulators on relative growth rate (g g^{-1} day^{-1}) at 30-60 DAS

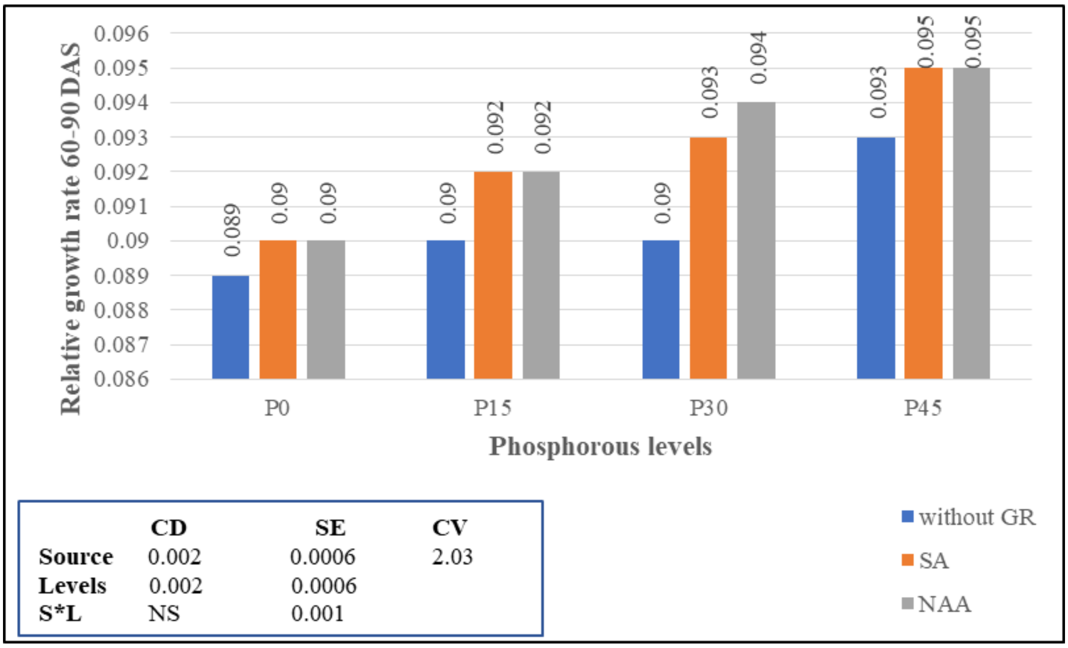

Fig 4.b: Effect of phosphorous and growth regulators on relative growth rate (g g^{-1} day^{-1}) at 60-90 DAS

7. Number of primary branches

The data is relevant to primary branches at 90 DAS and harvest stage have been presented in figure 5. (a.b). At 90 DAS and at harvest stage the application of growth regulators had significant effect on primary branches. The highest number of primary branches was obtained with the application of NAA 40ppm i.e., (4.57 and 6.55) and lowest in without growth regulators i.e., (4.05 and 5.89) was founded. At 90 DAS & harvest stage, application of NAA 40 ppm increased primary branches (12.8 & 11.2%) when compared to without growth regulators. The increasing level of phosphorous had significant effect on primary branches at 90 DAS and harvest stage. The highest number of primary branches was recorded with the application of 45 kg P_2O_5/ha i.e., (4.90 and 7.16) and lowest number of primary branches in 0 kg P_2O_5/ha i.e., (3.78 and 5.40) was founded. At 90 DAS and harvest stage, application of 45 kg P_2O_5/ha increased primary branches to the magnitude of (29.6 & 32.6%) when compared to control (0 kg P_2O_5/ha). At 90 DAS the interaction effect of growth regulators and phosphorous levels had no significant effect on primary branches. At harvest stage interaction shows significant effect on number of primary branches. the application of 45 kg P_2O_5/ha+ NAA 40ppm results highest number of primary branches (7.4) followed by 45 kg P_2O_5/ha+ SA 100 ppm (7.3). application of NAA 100ppm influenced number of branches in mustard (Kumar *et al*., 2018) [10]. Effect of different levels of phosphorous increased number of primary branches in mustard (Singh *et al*., 2016).

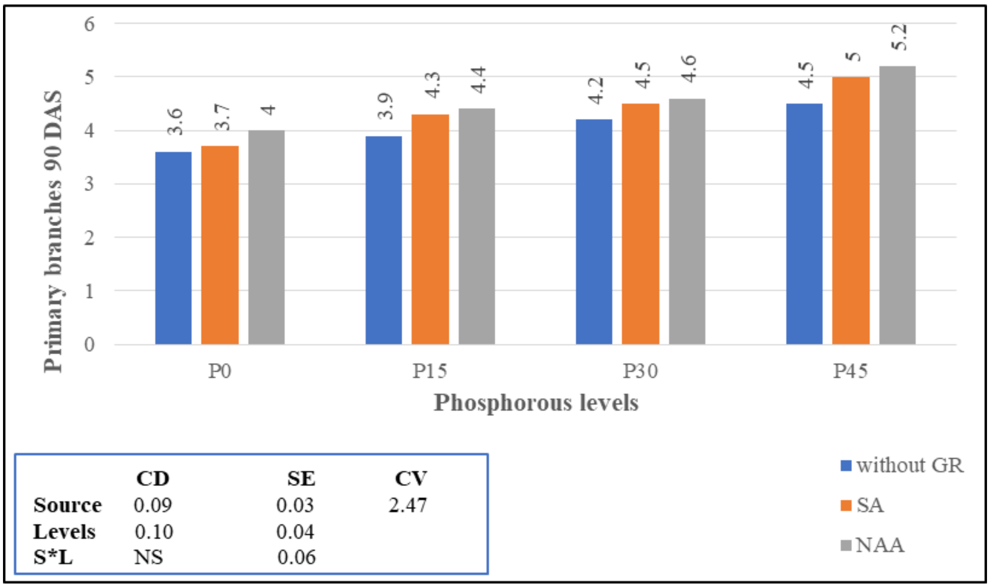

Fig 5.a: Effect of phosphorous and growth regulators on number of primary branches at 90 DAS

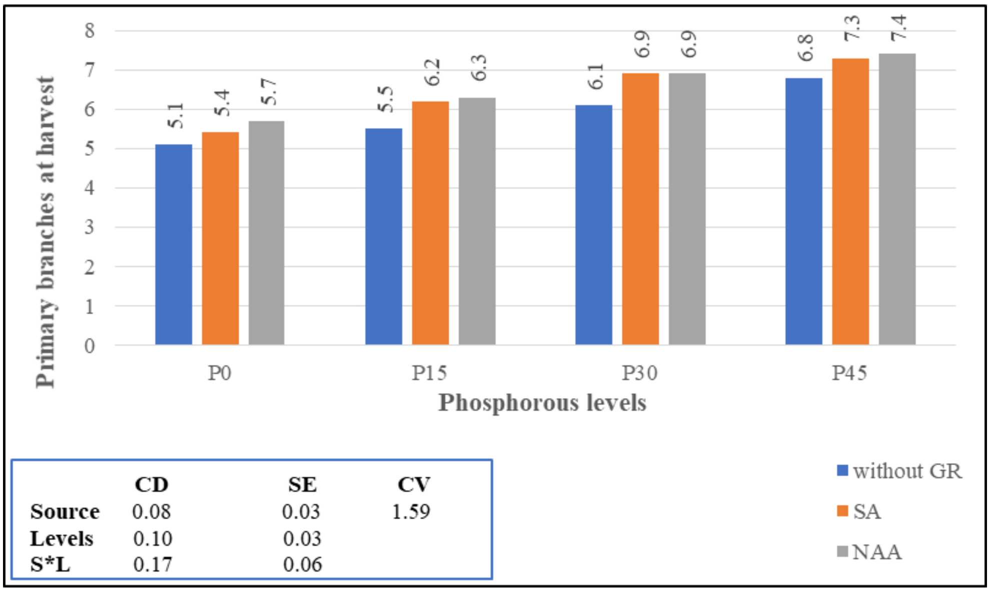

Fig 5.b: Effect of phosphorous and growth regulators on number of primary branches at harvest stage

8. Number of secondary branches

The data revealed to secondary branches at 90 DAS and harvest stage have been presented in figure 6. (a.b). At 90 DAS and at harvest stage the application of growth regulators had significant effect on secondary branches. The highest number of secondary branches was obtained with the application of NAA 40ppm i.e., (6.0 and 9.4) and lowest in without growth regulators i.e., (5.2 and 8.5) was recorded. At 90 DAS and harvest stage, application of NAA 40ppm increased secondary branches to the extent of (15.4 & 10.6%) when compared to without growth regulator. The increasing level of phosphorous had significant effect on secondary branches at 90 DAS and harvest stage. The highest number of secondary branches was recorded with the application of 45 kg P_2O_5/ha i.e., (6.5 and 10.2) and lowest number of secondary branches was observed in 0 kg P_2O_5/ha i.e., (4.8 and 8.0) was recorded. At 90 DAS and harvest stage, application of 45 kg P_2O_5/ha increased secondary branches by a tune of (35.4 & 27.5%) when compared to control (0 kg P_2O_5/ha). At 90 DAS and at harvest stage interaction effect of growth regulators and phosphorous levels had significant effect on number of secondary branches. The application of 45 kg P_2O_5/ha+ NAA 40ppm was observed highest number of secondary branches (6.9 and 10.8) followed by 45 kg P_2O_5/ha+ SA 100 ppm (6.5 and 10.4). According to (Kumar *et al.*, 2018) [10] application of NAA 100ppm influenced number of branches in mustard. Application of phosphorous increased number of secondary branches in mustard (Singh *et al.*, 2016).

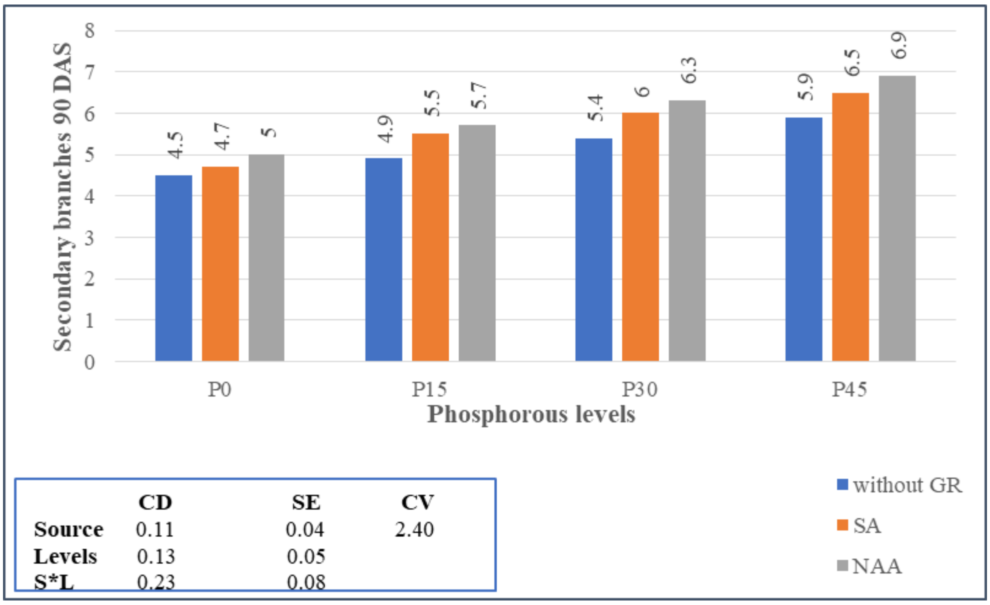

Fig 6.a: Effect of phosphorous and growth regulators on number of secondary branches at 90 DAS

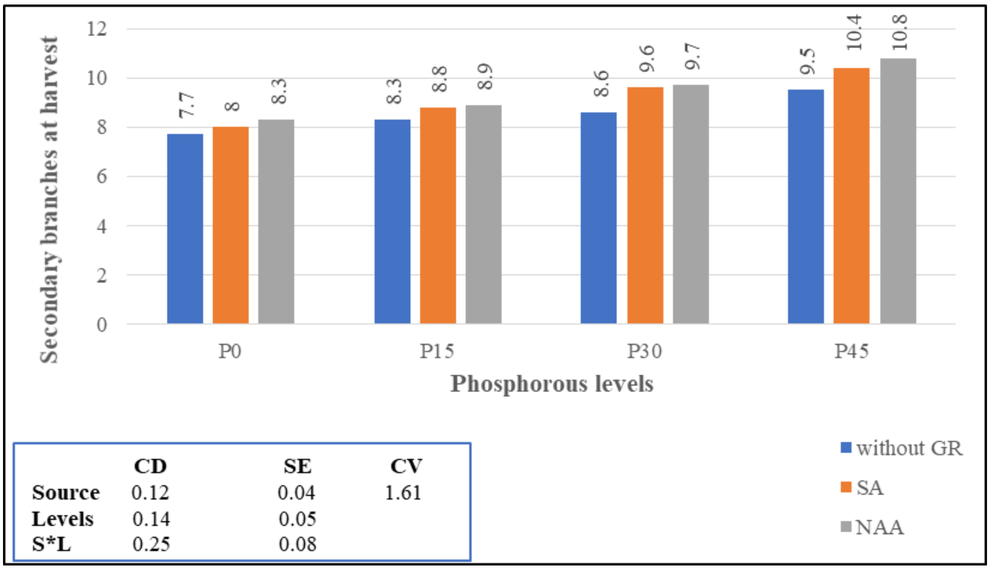

Fig 6.b: Effect of phosphorous and growth regulators on number of secondary branches at harvest stage

9. Number of siliquae per plant

The data pertaining to number of siliquae per plant have been presented in figure 7. The application of growth regulators had significant effect on number of siliquae per plant. The highest number of siliquae per plant was recorded with the application of NAA 40ppm (285.3) and lowest in without growth regulator (246.4) was recorded. Application of NAA 40 ppm increased number of siliquae per plant to the magnitude of 15.8% when compared to without growth regulator. The increasing level of phosphorous had significant effect on number of siliquae per plant. The highest number of siliquae per plant was observed with the application of 45 kg P_2O_5/ha (319.7) and lowest number of siliquae per plant was observed in 0 kg P_2O_5/ha (227.6) was recorded. Application of 45 kg P_2O_5/ha increased number of siliquae per plant to the magnitude of 40.5% when compared to control (0 kg P_2O_5/ha). The interaction effect of growth regulators and phosphorous levels had shown significant effect on number of siliquae per plant. The application of 45 kg P_2O_5/ha+ NAA 40ppm was founded highest number of siliquae per plant (349) followed by 45 kg P_2O_5/ha+ SA 100 ppm (328). Application of SA 0.5 mM increased the number of siliquae per plant in mustard (Sharma *et al*., 2017) [27]. According to (Solanki, RL, Sharma, M. 2016) [23]. The application of phosphorous increased the number of siliquae per plant in mustard.

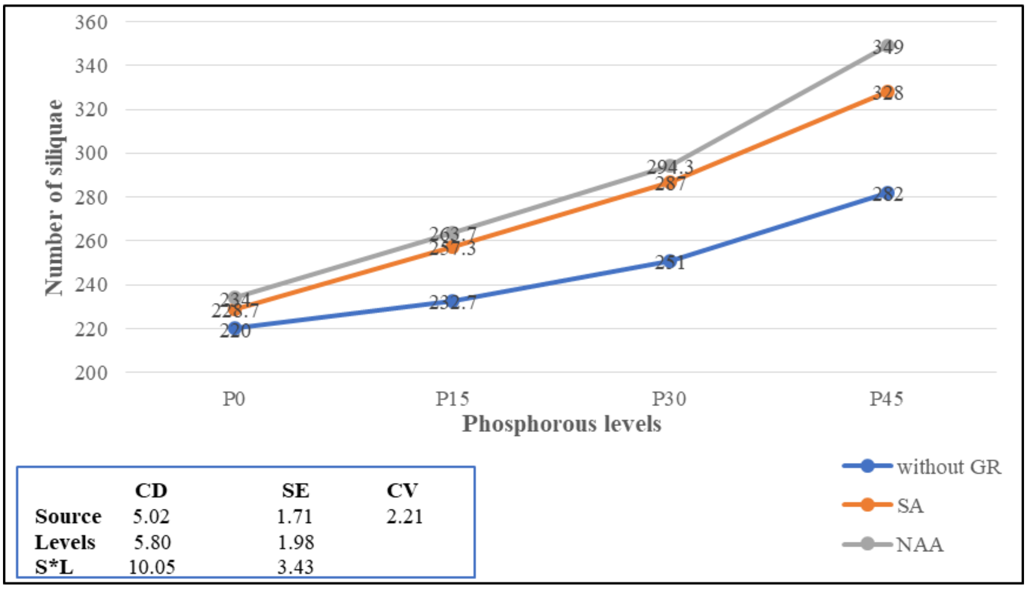

Fig 7: Effect of phosphorous and growth regulators on number of siliquae per plant

10. Siliquae length

The data indicates that siliquae length is given in figure 8, The application of growth regulators had significant effect on siliquae length. The highest siliquae length was recorded with the application of NAA 40ppm (7.1 cm) and lowest siliquae length was observed in without growth regulator (6.4 cm) was founded. Application of NAA 40 ppm increased siliquae length by a tune of 10.9% compared to without growth regulator. The increasing level of phosphorous had significant effect on siliquae length. The highest siliquae length was recorded with the application of 45 kg P_2O_5/ha (7.6 cm) and lowest siliquae length was observed in 0 kg P_2O_5/ha (6.1 cm). Application of 45 kg P_2O_5/ha increased siliquae length to the magnitude of 24.6% when compared to 0 kg P_2O_5/ha. The interaction effect of growth regulators and phosphorous levels had significant effect on siliquae length. The application of 45 kg P_2O_5/ha+ NAA 40ppm was recorded highest siliquae length (7.8 cm) followed by 45 kg P_2O_5/ha+ SA 100 ppm (7.72). Effect of phosphorous increased the length of siliquae in mustard (sunil nath *et al*., 2018).

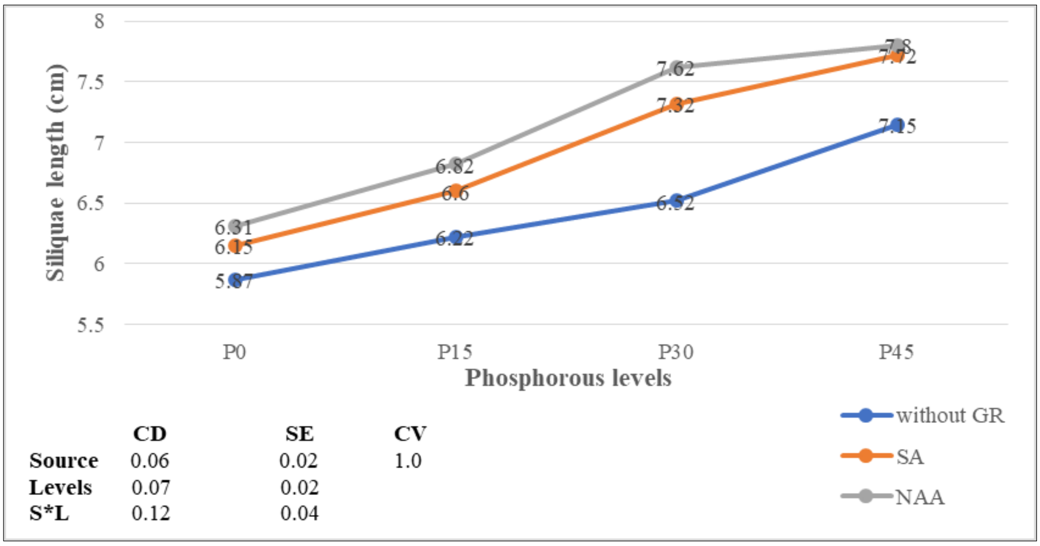

Fig 8: Effect of phosphorous and growth regulators on siliquae length (cm)

11. Number of seeds per siliquae

The data in respect to number of seeds per siliquae have been presented in figure 9. The application of growth regulators had significant effect on number of seeds per siliquae. The highest number of seeds per siliquae was recorded with the application of NAA 40ppm (26.6) and lowest number of seeds per siliquae was observed in without growth regulator (23.9) was noted. Application of NAA 40 ppm increased seeds per siliquae to the magnitude of 11.3% when compared to the without growth regulator. The increasing level of phosphorous had significant effect on number of seeds per siliquae. The maximum seeds per siliquae was recorded with the application of 45 kg P_2O_5/ha (28.2) and lowest seeds per siliquae was noted in 0 kg P_2O_5/ha (23.0). Application of 45 kg P_2O_5/ha increased seeds per siliquae by a tune of 22.6% when compared to control (0 kg P_2O_5/ha). The interaction effect of growth regulators and phosphorous levels had no significant effect on number of seeds per siliquae. Application of SA 0.5 mM influenced the number of seeds per siliquae in mustard (sharma *et al*., 2017). Application of different levels of phosphorous increased number of seeds per siliquae in mustard (Dhruw *et al*., 2017).

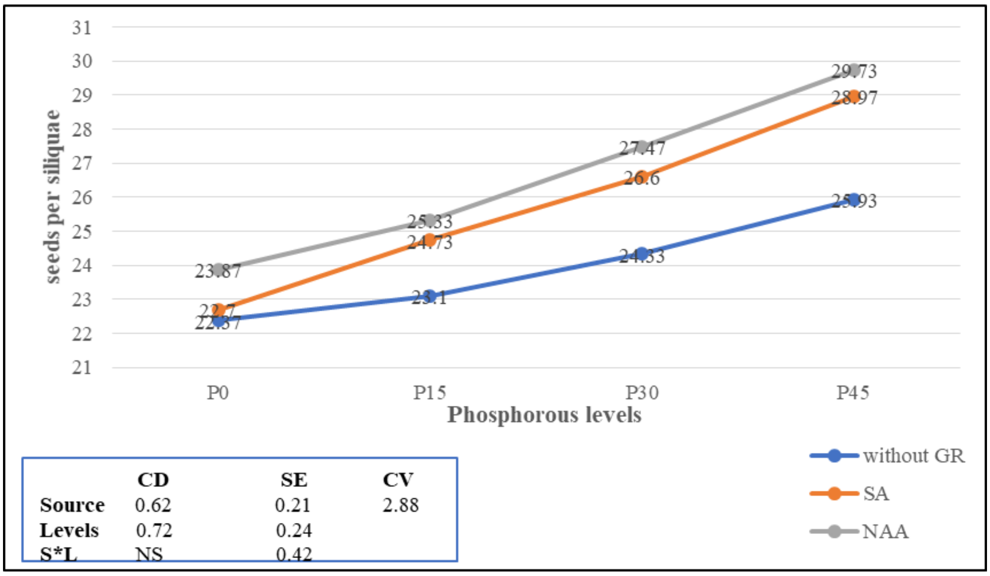

Fig 9: Effect of phosphorous and growth regulators on seeds per siliquae

12. Harvest index

Harvest index of gobhi sarson is given in figure 10. The application of growth regulators was significant effect on harvest index. The maximum harvest index was observed by the application of NAA 40 ppm (26.4) and minimum harvest index was recorded in without growth regulator (24.88) was noted. Application of NAA 40 ppm, SA 100 ppm increased the harvest index by a tune of 6.1, 3.3per cent respectively, when compared to the without growth regulators. NAA 40 ppm application remained on superior over without GR and remained on par with SA 100 ppm. The increasing levels of phosphorous was significant on harvest index of gobhi sarson. The maximum harvest index was recorded with the application of 45 kg P ha^{-1} (26.45) and minimum harvest index was recorded in 0 kg P ha^{-1} (24.22). Application of 15, 30 and, 45 kg P ha^{-1} increased the harvest index by the magnitude of 5.5, 9.0 and, 9.2 per cent respectively, compared to control (0 kg P ha^{-1}). The interaction effect of growth regulators and phosphorous levels was not significant on harvest index. Muhal. S *et al*. (2014) the foliar application of salicylic acid 100 ppm on *Brassica juncea* increased the harvest index of (28.2per cent). Kumar, N *et al*., (2016) the harvest index (42.45per cent) were maximum noted by the application of 60 kg phosphorus ha^{-1} in sunflower.

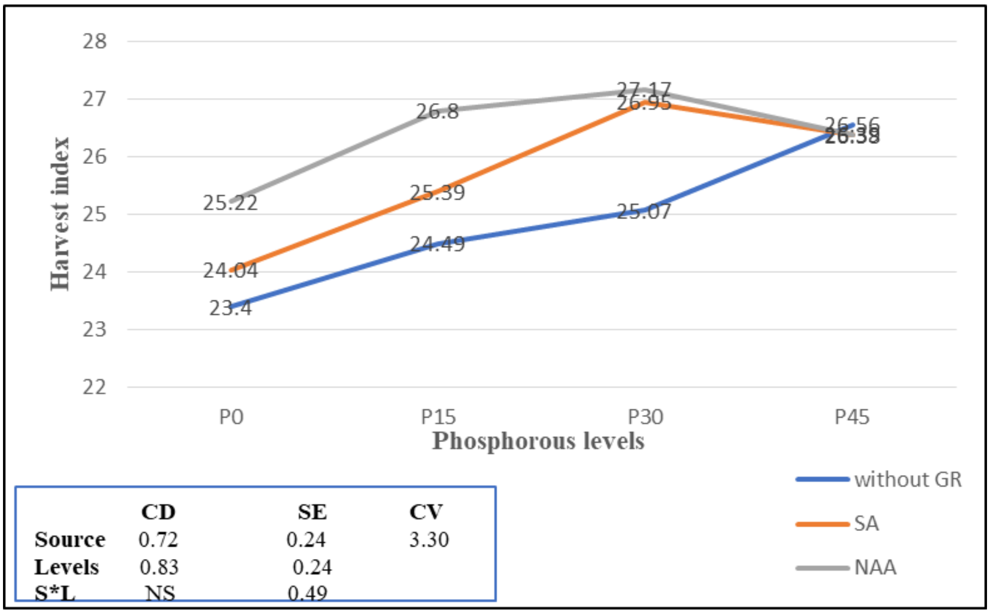

Fig 10: Effect of phosphorous and growth regulators on Harvest inde

13. Grain yield

The data pertaining to grain yield (t ha^{-1}) have been presented in figure 11. The application of growth regulators had significant effect on seed yield. The maximum grain yield was recorded with the application of NAA 40ppm (2.45 t ha^{-1}) and lowest grain yield was observed in without growth regulator (1.98 t ha^{-1}) was noted. Application of NAA 40 ppm increased grain yield by a tune of 23.7% when compared to the without growth regulator. The increasing levels of phosphorous had significant effect on grain yield. The maximum grain yield was observed with the application of 45 kg P_2O_5/ha (2.67 t ha^{-1}) and lowest grain yield was recorded in 0 kg P_2O_5/ha (1.77 t ha^{-1}). Application of 45 kg P_2O_5/ha increased grain yield to the magnitude of 50.8% when compared to control (0 kg P_2O_5/ha). The interaction effect of growth regulators and phosphorous levels had significant effect on grain yield. The application of 45 kg P_2O_5/ha+ NAA 40ppm was recorded the maximum grain yield (2.87 t ha^{-1}) followed by 45 kg P_2O_5/ha+ SA 100 ppm (2.74 t ha^{-1}). According to (Nehal *et al.*, 2018) application of growth regulator SA 0.7 mM had increased the seed yield in mustard. Application of different levels of phosphorous increased seed yield in mustard (Dhruw *et al.*, 2017).

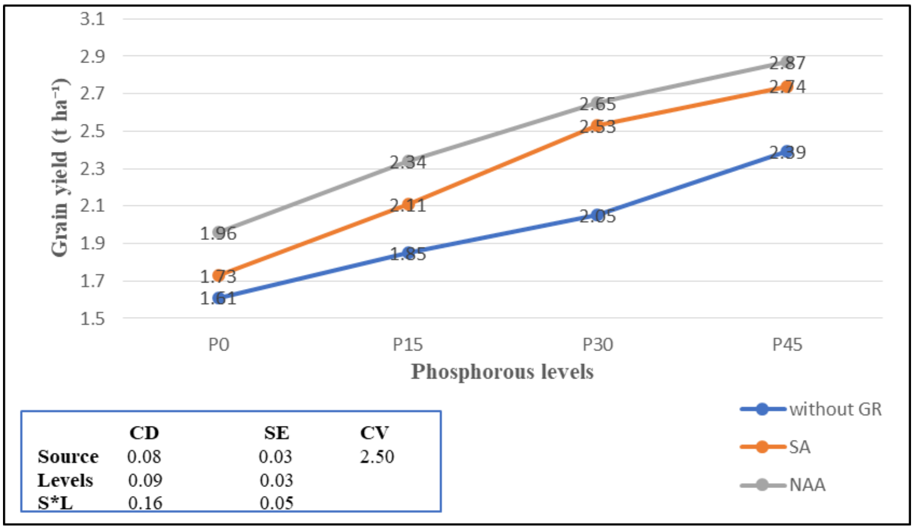

Fig 11: Effect of phosphorous and growth regulators on grain yield (t ha^{-1})

14. Straw yield

The data indicates that straw yield is given in figure 12, the application of growth regulators had significant effect on straw yield. The maximum straw yield was observed with the application of NAA 40 ppm (6.82 t ha^{-1}) and lowest straw yield was founded in without growth regulator (5.93 t ha^{-1}) was noted. Application of NAA 40 ppm increased straw yield by a magnitude of 15% when compared to the without growth regulator. The increasing levels of phosphorous had significant effect on straw yield. The maximum straw yield was recorded with the application of 45 kg P_2O_5/ha (7.42 t ha^{-1}) and lowest straw yield was observed in 0 kg P_2O_5/ha (5.51 t ha^{-1}). Application of 45 kg P_2O_5/ha increased the straw yield by a tune of 34.7% when compared to control (0 kg P_2O_5/ha). The interaction effect of growth regulators and phosphorous levels had significant effect on straw yield. The application of 45 kg P_2O_5/ha+ NAA 40ppm was recorded the maximum straw yield (8.0 t ha^{-1}) followed by 45 kg P_2O_5/ha+ SA 100 ppm (7.65 t ha^{-1}). According to (Sunil Nath *et al.*, 2018) application of different levels of phosphorous increased the straw yield in mustard.

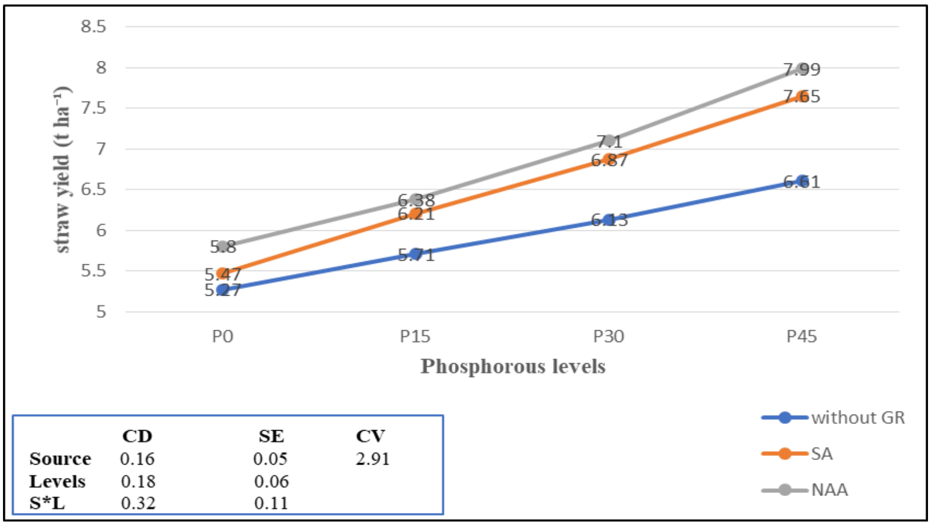

Fig 12: Effect of phosphorous and growth regulators on straw yield (t ha^{-1})

15. Phosphorous uptake in seed (kg/ha)

Phosphorous uptake in seed (kg ha^{-1}) of gobhi sarson have been presented in figure 13. The application of growth regulators was significant effect on phosphorous uptake in seed. maximum P uptake in seed was recorded with the application of NAA 40 ppm (8.64 kg ha^{-1}) and minimum P uptake in seed was observed in without growth regulator (8.31 kg ha^{-1}). Application of NAA 40 ppm, SA 100 ppm increased the P uptake in seed to the magnitude of 4.0, 3.7per cent respectively, compared to the without growth regulator. NAA 40 ppm application remained on superior over without GR and remained on par with SA 100 ppm. Application of phosphorous levels was significant effect on P uptake in seed. The maximum P uptake in seed was recorded by the application of 45 kg P ha^{-1} (12.16 kg ha^{-1}) and minimum P uptake in seed was founded in 0 kg P ha^{-1} (4.84 kg ha^{-1}). Application of 15, 30 and, 45 kg P ha^{-1} increased the P uptake in seed to the tune of 50, 103.1 and, 151.2 per cent when compared to control (0 kg P ha^{-1}). The interaction effect application of growth regulators and phosphorous levels was not significant on P uptake in seed. the foliar application of salicylic acid 100 ppm on *Brassica juncea* increased the P uptake in seed of (6.33 kg ha^{-1}) (Muhal S *et al*., 2014).

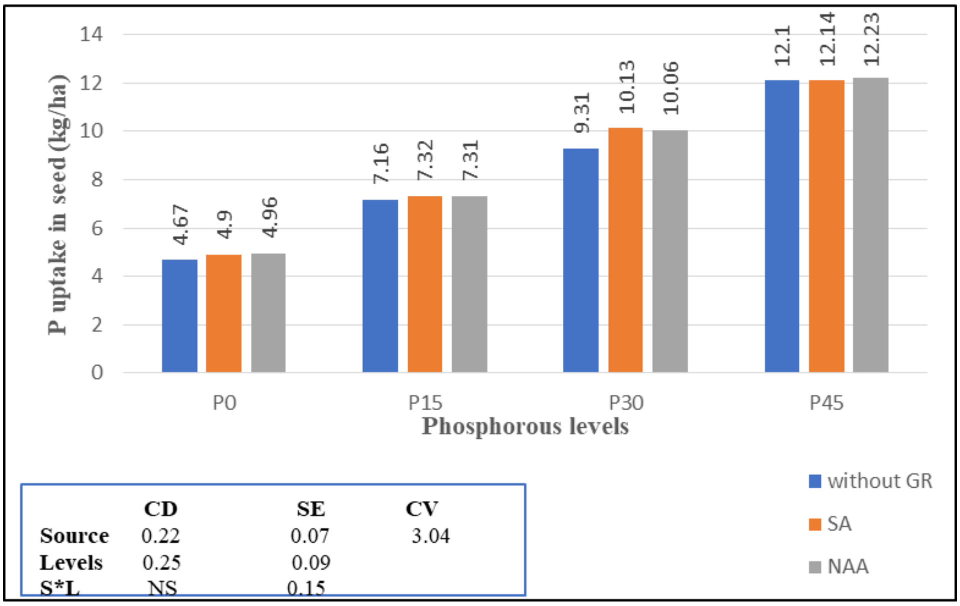

Fig 13: Effect of phosphorous and growth regulators on Phosphorous uptake in seed (kg/ha)

16. Phosphorous uptake in straw (kg/ha)

Phosphorous uptake in straw of gobhi sarson is given in figure 14. The application of growth regulators was significant effect on P uptake in straw. The maximum P uptake in straw was recorded with the application of NAA 40 ppm (14.41 kg ha^{-1}) and lowest P uptake in straw was observed in without growth regulator (12.10 kg ha^{-1}). Application of NAA 40 ppm, SA 100 ppm increased the P uptake in straw to the magnitude of 19.1, 15.7 per cent when compared to the without growth regulator. The NAA 40 ppm application remained on superior over without GR and SA 100 ppm. Application of phosphorous levels had significant effect on P uptake in straw of gobhi sarson. The highest P uptake in straw was recorded by the application of 45 kg P ha^{-1} (20.03 kg ha^{-1}) and lowest P uptake in straw was founded in 0 kg P ha^{-1} (6.95 kg ha^{-1}). Application of 15, 30 and, 45kg P ha^{-1} increased the P uptake in straw to the tune of 57.4, 131.7 and, 188.2 per cent respectively, compared to control (0 kg P ha^{-1}). The 45kg P ha^{-1} application remained on superior over 0, 15, 30kg P ha^{-1}. The interaction effect of application of growth regulators and phosphorous levels was significant on P uptake in straw. The application of 45 kg P ha^{-1} + NAA 40ppm was noted maximum P uptake in straw (22.3 kg ha^{-1}) followed by 45 kg P ha^{-1} + SA 100 ppm (20.6 kg ha^{-1}). Muahal, S *et al*., (2014) The foliar application of salicylic acid 100 ppm on *Brassica juncea* increased the P uptake in straw of (11.74 kg ha^{-1}). Dhage, S. J *et al*., (2014) the application of P 75 kg ha^{-1} significantly increased the phosphorous uptake of straw (10.56 kg ha^{-1}) and it was par with P 50 kg ha^{-1} (9.50 kg ha^{-1}).

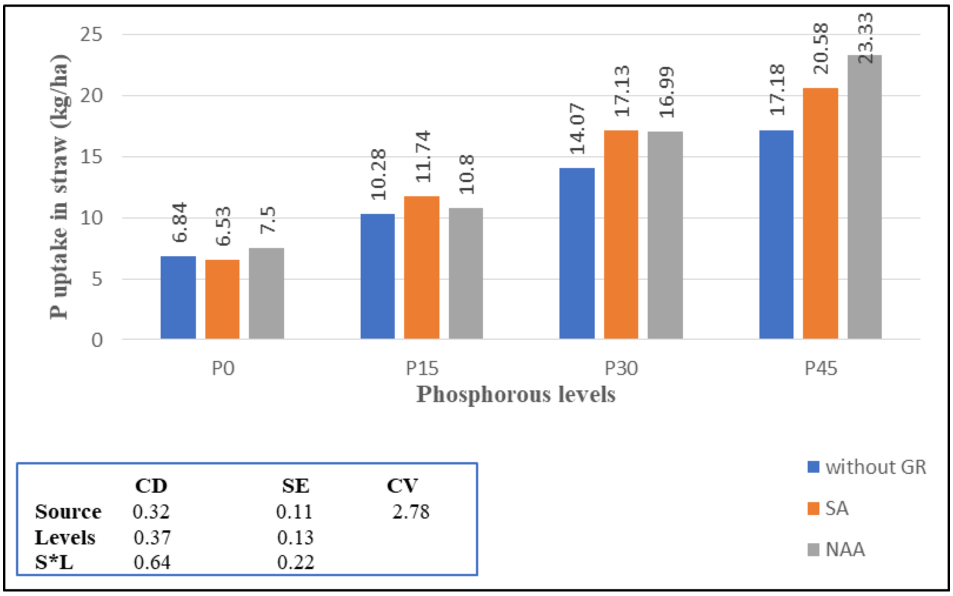

Fig. 14: Effect of phosphorous and growth regulators on Phosphorous uptake in straw (kg/ha)

17. Oil content (%)

Oil content of gobhi sarson have been presented in figure 15. The application of growth regulators was significant effect on oil content per cent. The maximum oil content was recorded by the application of NAA 40ppm (33.83) and minimum oil content was observed in without growth regulators (32.71). Application of NAA 40 ppm, SA 100 ppm increased the oil content to the magnitude of 3.4, 2.5per cent when compared to the without growth regulators. The NAA 40 ppm application remained on superior over without GR and remained on par with SA 100 ppm. The increasing level of phosphorous was significant effect on oil content. The maximum oil content was founded by the application of 45 kg P ha^{-1} (35.69) and minimum oil content was noted in 0 kg P ha^{-1} (31.58). Application of 30, 45 kg P ha^{-1} increased oil content by a tune of 6.0, 13.0 per cent, respectively, compared to the control (0 kg P ha^{-1}). The 45kg P ha^{-1} application remained on superior over 0, 15, 30kg P ha^{-1}. The interaction effect of application of growth regulators and phosphorous levels was not significant on oil content. The best rate of the NAA might have enriched enzyme activities; this implicates that oil synthesis resulted in increased amounts of oil in the seed (Ferdousi Begum *et al.*, 2018). Muhal. S *et al.* (2014) the foliar application of salicylic acid 100 ppm on *Brassica juncea* increased the oil content of (37.96per cent). Mishra, SV *et al.*, (2010) the application of 60 kg P_2O_5 ha^{-1} significantly improved the oil content 33.06per cent compared to control (29per cent).

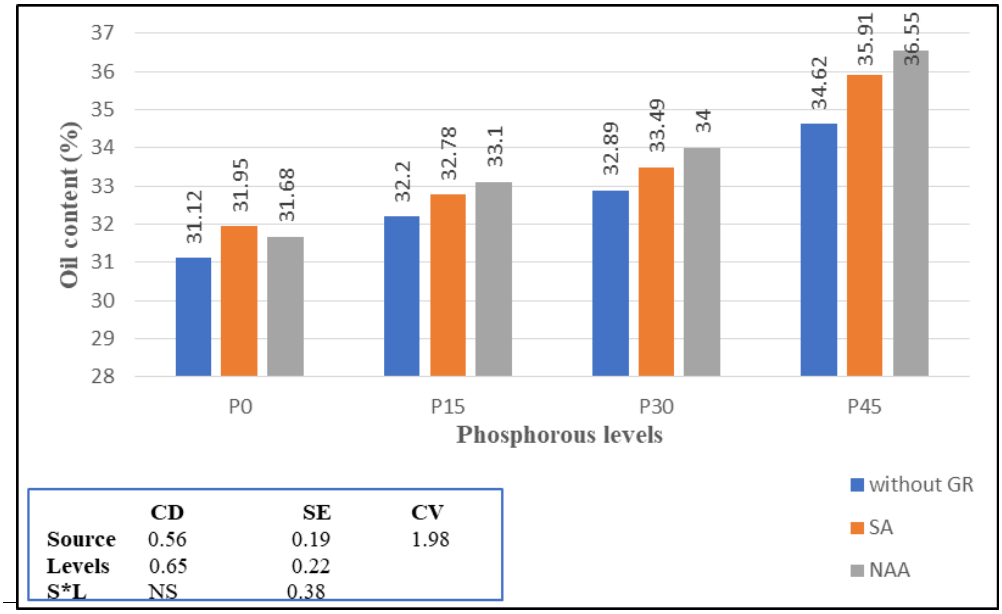

Fig 15: Effect of phosphorous and growth regulators on Oil content (%)

Conclusion

The present study indicates that, treatment combination of T_{12}, application of higher level of phosphorous i.e., 45kg P_2O_5 ha^{-1} along with growth regulator naphthalene acetic acid @40 ppm and followed by T_8 45kg P_2O_5 ha^{-1} with salicylic acid @ 100 ppm has recorded best treatment compared to others and resulted significantly higher growth and yield of gobhi sarson. The research findings will be used to conduct a multifaceted analysis to assess the effect of phosphorous and growth regulators on growth, yield and quality of gobhi sarson.

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