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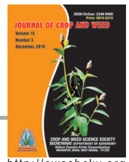

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Response of potato *(Solanum tuberosum* L.) to gibberellic acid and integrated potassium management

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ABSTRACT

A field experiment was conducted with potato at student research farm, Department of Agriculture, Khalsa College Amritsar. Two factors having three and five levels, were replicated thrice in a factorial randomized block design. The treatments were control (G_1), gibberellic acid (G_2, seed application) and gibberellic acid (G_3, foliar application) in factor A and factor B includes control of potassium (K_1), 100 per cent potassium through a recommended dose of fertilizer (K_2), integrated application of potassium from K-biofertilizer along with 75 per cent recommended dose of potassium (K_3), integrated application of potassium from K-biofertilizer along with 50 per cent recommended dose of potassium(K_4), K-biofertilizer only (K_5). Results revealed that the foliar application and seed application of gibberellic acid significantly affected both growth parameters and yield parameters in potato except disease and pest incidence parameters. Maximum tuber yield was recorded under G_3 (181.20 q ha^{-1}) and G_2 (176.27 q ha^{-1}) treatments as compared to control (162.86 q ha^{-1}). Both 100% RDF and 75% recommended dose of potassium + K-biofertilizer may be recommended for higher tuber yield and disease management under Amritsar conditions. B: C ratio of both G_2 and G_3 (1.20 or 1.28) and K_3 or K_2 treatment (1.46 or 1.58) was higher than other treatments also. No interaction between GA_3 and IPM was found significant.

Keywords: Potato, potassium, K-biofertilizer, gibberellic acid, yield.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a starchy crop and belongs to the Solanaceae family. It is believed that potato is originated in Southern Peru. It appears as the fourth most important food crop in India after cereal crops (Rice, Wheat, and Maize). It can supplement the food needs of the country substantially as it produces more dry matter food per unit area than other major food crops. Potatoes are providing starch, vitamins (B_1, B_2, B_6 and C) and minerals (Ca, P, Fe). It also contains a good amount of essential amino acids. In India, since 1935 with the establishment of Central Potato Research Institute at Shimla, research on developing new strains of potato is in progress. Although a lot of agronomical trials on spacing, weed, and irrigation management aspects have been conducted to increase the production in India, less attention has been paid to the use of plant growth regulators on boosting up yield of the potato crop. Potato tuberization is a complex process involving anatomical, enzymatic, biochemical, and hormonal changes leading to the differentiation of the stolon into a vegetative storage organ (Tekalign *et al*., 2005). The growth hormones may be defined as any organic compounds, which are active at low concentrations in promoting, inhibiting, or modifying growth and development. Gibberellin application enhanced shoot emergence, increased shoot height, stems per hill, and several tubers per hill. The application of gibberellic acid was recommended for early germination and to increase the average weight of tuber (Sillu *et al*., 2012). In modern intensive agriculture, the natural supply of potassium is not adequate to sustain yields, further continued use of chemical fertilizers causes nutritional imbalance. Thus potassium management is required for better production of the crop. Further, considerable improvement in quality and yield of potato has been observed under the integrated use of organic and inorganic fertilizers as compared to inorganic fertilizers alone (Raghav *et al*., 2009). *Frateuria aurentia* or potassium mobilizing bacteria is an important free-living soil bacteria isolated from the rhizosphere of plants and belonging to the family Pseudomonaceae. The organic fertilizer in the form of biofertilizer such as potassium mobilizer biofertilizer shows the increase in yield and growth attributes of potatoes and it helps to make unavailable form of potassium to available form which is already present in the soil to potato and also fix soil potassium reserves (Saikia *et al*., 2006). Hence, the consumption of potassium mobilizing bacteria can be an effective alternative to chemical fertilizers. The

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combined application of biofertilizer and chemical fertilizer along with growth regulators can improve growth, quality, and yield of potato. As per the above-stated facts the study entitled "Response of potato (*Solanum tuberosum* L.) to gibberellic acid and integrated potassium management" was planned.

MATERIALS AND METHODS

A field experiment (2017-18) was laid out in a Factorial RBCD design with three gibberellic acids (GA_3) treatments in main–plots and five potassium (K) management treatments along with K bio-fertilizers in subplots and replicated thrice. GA_3 treatments were Control (G_1), GA_3 seed application at sowing time (G_2), and GA_3 foliar application at 30 days after sowing (30 DAS) (G_3). Potassium management practices were Control (K_1), 100% recommended dose of potassium @ 62.5 kg K_2O per ha (RDP) through inorganic fertilizer (K_2), 75% recommended dose of K through inorganic fertilizers + K-biofertilizer (K_3), 50 % recommended dose of K through inorganic fertilizers + K-biofertilizer (K_3) and K-biofertilizer (K_5) only. 'Lady Rosetta' potato hybrid was sown in October and harvested in January in the *rabi* season of 2017-18. The tubers were planted at 20 cm apart in the furrows of 60 cm distance and covered immediately after planting. Well decomposed FYM was applied at15 days before final land preparation. Half dose of N and a full dose of P and K were applied as per treatment as basal dose before planting. The earthing up was done at 30 days after planting along with weeding to facilitate the development of tubers at the stolon tips. During earthing up the remaining nitrogen dose was side dressed and mixed thoroughly with the soil. The experimental data were statistically analyzed by factorial design (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Phonological parameters

Early tuber emergence and initiation were observed in the treatment of GA_3 seed treated plots (Table 1). The results conformed to the findings of Barani *et al.* (2013) and Farhatullah *et al.* (2007). Early tuber initiation in GA_3 treatment occurred due to early plant emergence and stem development. While the plants under control G_1 and G_3 took the maximum time (27.20 and 27.26 days) for tuber initiation and was statistically inferior to other treatments. They reported that GA_3 (seed treatment) improved the days taken to emergence by sprouted earlier. Days taken for tuber emergence and initiation were remained unaffected by different integrated potassium management treatments. The uniform plant population was observed in all Factors.

Growth parameters

Growth attributes such as plant height, leaf area index, number of stems, dry matter accumulation, and dry matter content of tubers and haulm along with stem girth differed significantly due to different GA_3 and integrated potassium management treatments (Table 1). The highest plant height was recorded after 90 DAS with the foliar application (52.39cm) and seed application (50.55cm) of GA_3 as compared to control. The increase in plant height at the foliar application of plant growth regulators may be due to better penetration effect on leaves and resulted in increased leaf chlorophyll content (Awati and Bhattacharya, 2016). The maximum leaf area index was noticed under the foliar application of GA_3 followed by seed application and control. A foliar application that was at par with seed application of gibberellic acid significantly better than control. Farhatullah *et al.* (2007) stated that the GA_3 increased the number of leaves plantlets^{-1} as compared to control. Data depicted in table 1and fig.2 revealed that at 30 DAS highest Dry matter accumulation was recorded in G_2 treatment followed by G_3 and G_1. At 60 DAS, the highest DMA was recorded in G_3 and G_2 as compared to G_1 treatment. However foliar and seed application of gibberellic acid was statistically at par with each other. Similar statistical results were obtained at 90 DAS also. The results in the current study are in agreement with the results of Faten *et al*. (2008) who showed an increase in dry weight of shoots as a result of foliar application of GA_3 in potato. Data in the table revealed that periodic dry matter accumulation was also significantly influenced by different integrated potassium management treatments. Similar trends were also noticed in dry matter content in both haulm and tubers (Fig. 1 and 2). A maximum number of stems per hill were observed under the foliar application of GA_3 (5.52) which were at par with the seed application of GA_3 (5.24). Both were significantly higher than control (4.38). Number of stems per hill were significantly affected by potassium treatments. These results conform to the findings of Awati and Bhattacharya (2016), Kazemi (2014) in potato. Maximum stem girth was observed under foliar application of GA_3 which was at par with the seed application of GA_3. Both were significantly higher than control.

In integrated potassium management treatments, treatment K_2 (54.40 cm) being at par with treatment K_3 (53.62 cm) showed significantly higher plant height than K_4, K_5, and K_1. However, all treatments were found statistically higher than control after 30 DAS onwards. Al-moshileh *et al.* (2005) also observed that the plant height was significantly affected by potassium. In factor B, LAI was significantly affected by integrated potassium management treatments. Maximum plant height, LAI, dry matter accumulation was recorded in treatment K_2 after 30 DAS which were at par with treatment K_3. This increase in leaf area index through integrated potassium management may be attributed due to the quick and readily availability of major nutrients to plant at earlier stages of plant growth (Angadi *et al.,* 2017). In the early period of plant growth *i.e.* at 30 DAS difference due to integrated potassium management treatments was non-significant. At 60 DAS, higher DMA recorded in K_2 (35g) being par with K_3 (34.20g), showed higher dry matter accumulation rate than K_4, K_5, and K_1 (control). At 90 DAS, higher DMA was recorded in K_2 (72.71g) being par with K_3 (71.05g) followed by K_4, K_5, and K_1 (control). The percent increase in DMA was 44.3, 41, 26.3, and 14.5 in K_2, K_3, K_4 and K_5 respectively over K_1 at 90 DAS. Treatment K_4 and K_5 showed significantly higher DMA than control also. Moinuddin *et al.* (2004) also reported that the plant biomass was significantly affected by increasing potassium application. Similar trends were also noticed in dry matter content in both haulm and tubers (Fig. 1 and 2). In integrated potassium management treatments, the highest number of stems was found in treatment K_2 (5.83) which was at par with treatment K_3 (5.73) but significantly superior over K_4, K_5, and K_1. The minimum number of stems per hill was found in potassium control (4.02). A similar result was observed by Ayyub *et al.* (2011), Yadav *et al.* (2014), and Badoni *et al.* (2017) in potato. Stem girths were significantly affected by potassium treatments. The highest number of stems was found in treatment K_2 which was at par with treatment K_3 but significantly superior over K_4, K_5, and K_1. A minimum number of stems per hill were found in potassium control.

Yield attributing parameters

Yield attributing characters such as number of tubers and average tuber weight differed significantly among the GA_3 and integrated potassium management treatments during 2017-18 (Table 2). All the gibberellic acid treatments were significantly better than control. Treatment G_3 (7.57) being at par with treatment G_2 (7.28) showed a significantly higher number of tubers than G_1 (control) at 60 DAS. At 90 DAS, the trend was in favor of $G_3 > G_2 > G_1$. Treatment G_3 (8.51) showed a significantly higher tuber number than treatment G_2 (8.11) and treatment G_1 (6.74). However, both foliar and seed application was at par with each other in observation of number of tuber at 90 DAS. Virtanen *et al.* (2013) stated that GA_3 treatments significantly increased the number of tubers in the cultivar *Fambo*. The highest tuber weight per plant was recorded under foliar and seed application of gibberellic acid at 30 DAS intervals. Both foliar and seed application was statistically par with each other. Minimum haulm and tuber yield were recorded in control (Table 2).

The data about the number of tubers presented in Table 2 indicated that the number of tubers differed significantly among various integrated potassium management treatments. A maximum number of tubers per plant (7.70) at 60 DAS was given by treatment K_2 and was found to be at par with treatment K_3 (7.62). At 90 DAS, the maximum number of tubers per plant (8.59) was given by K_2 treatment and was found to be at par with treatment K_3 (8.58). The increase in the number of tubers per plant caused by integrated potassium management resulted mainly because of the application of potassium to certain limits, the number of tubers per plant was found promoted whereas, and the excessive potassium produced negative impacts (Pervez *et al.,* 2013) and potassium application increased the number of tubers by helping in the accumulation of carbohydrates (Bhattarai and Swarnima, 2016). In potassium management treatments, the highest average tuber weight was recorded in treatment K_2 being at par with treatment K_3 followed by K_4 and K_5 treatments. The lowest value of dry matter content was found in potassium control (K_1).

Tuber yield

Tuber yield is the function of the assimilation of carbon in the production and translocation of photosynthates. The perusal of the data depicted in the Table 2 revealed that the yield varied among the treatments. The result in the table shows that treatment G_3 (181.20 q ha^{-1}) showed a higher amount of tuber yield as compared to G_2 (176.27 q ha^{-1}) and control (162.86 q ha^{-1}) treatments. Per cent increment in the yield compared to best treatment G_2 and G_3 over G_1 (control) was 8 per cent to 11 per cent. Seed treatment of GA_3 increased yield of potato because tubers sprouted earlier, while non-application of GA_3 sprouted very late and slow. Sekhon and Singh (1984) also reported that the GA_3 resulted in the production of 2.1 tonnes ha^{-1} more seed than the water soaked-control. Barani *et al.* (2013) also stated that the application of gibberellic acid increased the productivity of tubers of potato. El-Hamady (2017) also concluded that the increasing concentration of GA_3 markedly increased tuber yield in potato. In integrated potassium treatments, data in the Table 2 revealed that all potassium treatments were significantly better than control. The trend was in favor of $K_2 > K_3 > K_4 > K_5 > K_1$. All treatments were significantly affecting the tuber yield. Treatment K_2 (191.01 q ha^{-1}) showed significantly higher tuber yield than K_3, K_4, K_5 and control. However, treatments K_2 and K_3 were statistically par with each other. The

Table 1: Effect of GA_3 and integrated potassium management on growth attributes of potato.

	Symbol	Days taken to the emergence	Plant population (percent)	Days taken to tuber initiation (days)	Number of stem per hill	Stem girth	Plant height (cm)			Leaf area index			Dry matter accumulation (g)		
							30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Factor A (Gibberellic Acid)															
Control (No Gibberellic acid)	G_1	16.60	94.20	27.20	4.38	11.48	9.86	38.99	45.01	0.29	2.91	2.16	8.08	28.06	57.95
GA_3 Seed application @50 ppm	G_2	13.66	97.20	25.00	5.24	13.29	11.97	44.57	50.55	0.34	3.47	2.54	10.72	31.06	64.31
GA_3 Foliar application @50 ppm	G_3	16.46	94.13	27.26	5.52	13.79	9.90	46.97	52.39	0.28	3.63	2.68	8.09	32.36	67.02
SE(m)		**0.551**	**1.55**	**0.68**	**0.13**	**-**	**0.36**	**0.86**	**0.85**	**0.01**	**0.09**	**0.07**	**-**	**-**	**-**
LSD (p = 0.05)		**1.60**	**NS**	**1.99**	**0.38**	**0.79**	**1.05**	**2.52**	**2.49**	**0.02**	**0.27**	**0.20**	**0.05**	**2.13**	**4.42**
Factor B (Integrated potassium management)															
Control (No K application)	K_1	16.77	94.66	26.88	4.02	10.73	9.73	36.40	42.70	0.27	2.58	1.92	8.57	24.30	50.38
100percent Recommended Dose of K	K_2	14.44	95.77	26.00	5.83	14.54	11.55	48.77	54.40	0.32	3.89	2.85	9.42	35.00	72.71
75percent Recommended Dose of K + K-Biofertilizer	K_3	14.88	95.44	26.11	5.73	14.30	11.10	48.10	53.62	0.31	3.86	2.81	9.08	34.20	71.05
50percent Recommended Dose of K + K-Biofertilizer	K_4	15.66	95.11	26.66	5.12	12.97	10.47	44.25	49.55	0.31	3.37	2.50	8.96	31.11	63.65
K-Biofertilizer	K_5	16.11	94.88	26.77	4.53	11.90	10.03	40.03	46.33	0.30	3.01	2.21	8.77	27.85	57.70
SE(m)		**0.711**	**2.00**	**0.88**	**0.16**	**-**	**0.47**	**1.21**	**1.10**	**0.01**	**0.12**	**0.09**	**-**	**-**	**-**
LSD (p = 0.05)		**NS**	**NS**	**NS**	**0.49**	**1.03**	**NS**	**3.26**	**3.21**	**NS**	**0.35**	**0.26**	**NS**	**2.76**	**5.71**
CV		11.48	6.32	10.01	10.05	7.05	6.67	7.72	13.37	12.69	10.97	10.99	-	-	-

Table 2: Effect of GA_3 and integrated potassium management on yield and yield attributes of potato.

	Symbol	Haulm yield (q ha^{-1})	Total tuber yield(q ha^{-1})	Number of tubers		Average tuber weight (g)			Total input cost (Rs. Ha^{-1})	Gross returns (Rs. Ha^{-})	Net returns (Rs. Ha^{-1})	B:C ratio
				60 DAS	90 DAS	30 DAS	60 DAS	90 DAS				
Factor A (Gibberellic Acid)												
Control (No Gibberellic acid)	G_1	52.33	162.86	6.26	6.74	6.03	69.79	209.39	54563	110194	55631	1.01
GA_3 Seed application @50 ppm	G_2	56.86	176.27	7.28	8.11	7.73	75.54	226.64	56314	124274	67961	1.20
GA_3 Foliar application @50 ppm	G_3	58.45	181.20	7.57	8.51	6.04	77.65	232.97	55613	127260	71647	1.28
SE(m)		**1.03**	**3.19**	**0.12**	**0.15**	**0.10**	**1.36**	**4.10**	-	-	-	-
LSD (p = 0.05)		**2.99**	**9.29**	**0.36**	**0.45**	**0.31**	**3.98**	**11.95**	-	-	-	-
Factor B (Integrated potassium management)												
Control (No K application)	K_1	48.40	150.04	6.10	6.59	6.49	64.30	192.91	53593	93285	39692	0.74
100percent Recommended Dose of K	K_2	61.61	191.01	7.70	8.59	6.70	81.86	245.59	54763	141447	86684	1.58
75percent Recommended Dose of K + K-Biofertilizer	K_3	60.68	188.11	7.62	8.58	6.62	80.61	241.86	55820	137487	81667	1.46
50 percent Recommended Dose of K + K-Biofertilizer	K_4	56.61	175.49	7.14	7.92	6.62	75.21	225.63	55528	122876	67348	1.21
K-Biofertilizer	K_5	52.44	162.57	6.62	7.25	6.58	69.67	209.01	54943	107781	52838	0.96
SE(m)		**1.32**	**4.12**	**0.16**	**0.20**	**0.13**	**1.76**	**5.29**	-	-	-	-
LSD (p = 0.05)		**3.87**	**11.99**	**0.46**	**0.58**	**NS**	**5.14**	**15.42**	-	-	-	-
CV		**7.12**	**7.14**	**8.90**	**6.83**	-	-	-	-	-	-	-

maximum tuber yield was recorded with treatment K_2 (191.01 q ha^{-1}) and K_3 (188.11 q ha^{-1}). The lowest total tuber yield was given by control treatment (150.04 q ha^{-1}). The per cent increase in tuber yield was 27.3, 25.3, 16.9, and 8.3 in K_2, K_3, K_4 and K_5 respectively over K_1. The results in the current study are in agreement with the results of Singh and Lal (2012) who also reported that the total tuber yield was increased significantly with each increment of potassium. Gauhar and Raghav (2008), Kumar *et al.* (2017) Islam *et al.* (2013 a, b), and Badoni *et al.* (2017) also reported similar results.

Haulm yield

In the gibberellic acid treatment data depicted in Table 2 revealed that biological yield was influenced significantly due to different treatments. It was also observed that the foliar application and seed application of GA_3 took a slightly higher biological yield in the form of haulm yield than control. It may be because of increases in tuber yield in the corresponding treatments. In integrated potassium management treatments, data depicted in Table 2 revealed that all treatments were found significant. Haulm yield trend was in favor of $K_2 > K_3 > K_4 > K_5 > K_1$ (control). This trend is similar related to the tuber yield. However, all potassium treatments having an organic and inorganic source of potassium or combination significantly improved haulm yield as compared to the control of potassium. The interaction effect of gibberellic acid and integrated potassium management on haulm yield was also found non-significant.

Economics

Economic analysis of integrated nutrient management of potato crop was done using total input cost, gross returns, and net income concepts in Rs. per ha for the year 2017-18. The total input cost consisted of cost of cultivation including the investments on various cultural practices performed, manures and fertilizers, pesticides used. Net income was estimated by deducting total input costs from gross returns. The presented data from Table 2 revealed that treatment G_3 and G_2 gave maximum returns (Rs. 71647 per ha and Rs. 67961 per ha) along with maximum B: C ratio (1.28 and 1.20). Also, it was concluded that treatment G_1 and G_2 yielded maximum tuber yield as well as growth characters.

In integrated potassium management treatments, K_1 (control) gave minimum returns as compared to other integrated potassium treatments. Hence, it was clear from the data that treatment K_2 and K_3 were found more economical as it solved the purpose in both the ways one is changing the trend of using more inorganic fertilizers towards biofertilizer and second being getting

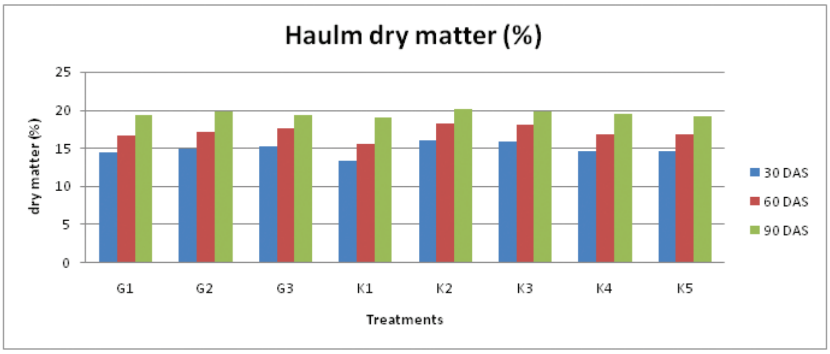

Fig. 1: Effect of GA_3 and integrated potassium management on the haulm dry-matter content of the potato.

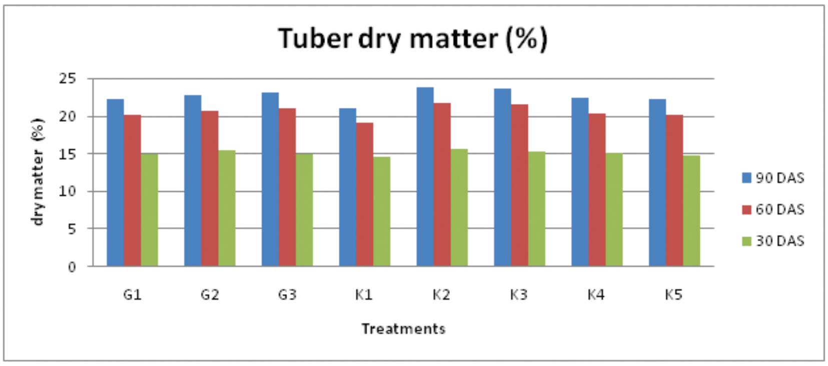

Fig. 2: Effect of GA_3 and integrated potassium management on tuber dry-matter content of the potato.

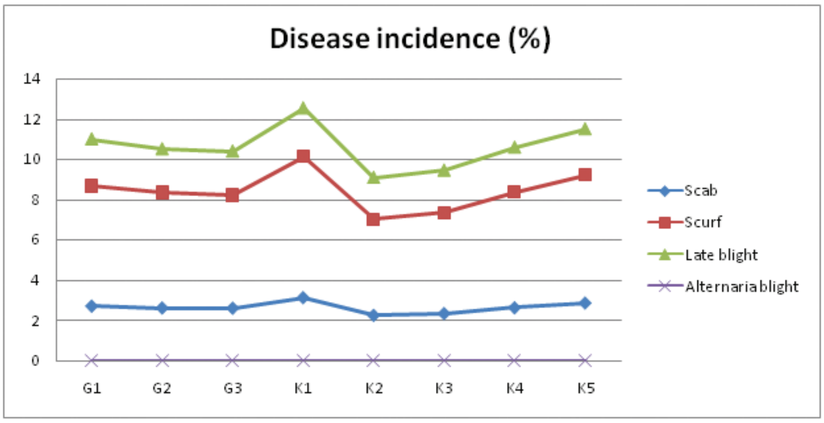

Fig. 3: Effect of GA_3 and integrated potassium management on disease incidence of potato (Mean season).

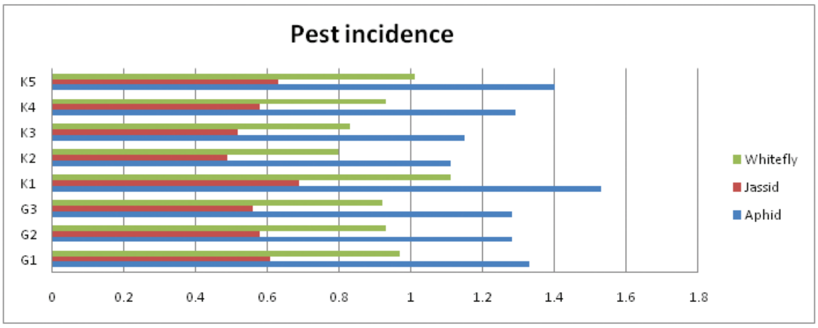

Fig. 4: Effect of GA_3 and integrated potassium management on pest incidence of potato (mean season).

*Mean incidence is calculated from occurrence of pests according to meteorological weeks.

higher returns and B: C ratio (1.58 and 1.46). The result follows the report made by Zelelew *et al.* (2016)

Disease incidence

Disease incidence of late blight, Alternaria blight, scurf, and the scab was not affected significantly by gibberellic acid treatments (Fig. 3). In integrated potassium management treatments, the highest incidence of diseases was observed with K_1 treatment during the experiment. The lowest mean incidence of diseases was observed with K_2 and was statistically at par with K_3. A maximum occurrence of late blight disease was noticed during the experiment, whereas no symptoms of Alternaria blight were observed during the experiment. Potassium increases the resistance of plants to stress and supports the natural defenses of plants against pathogens such as *Phytophthora infestans* and *Alternaria* spp. (Feng and Zheng, 2006; Machinandiarena *et al.* 2012).

Pest incidence

The pest incidence did not differ significantly among the treatments of organic and inorganic fertilizers. In integrated potassium management treatments, the highest incidence of pest was observed with K_1 treatment during the experiment (Fig. 4). The lowest mean incidence of the pest was observed with K_2 and was statistically at par with K_3. Major pest incidence was done by aphid > jassid > whitefly in the experiment location. Khairnar and Patel (2015) also reported a higher incidence of aphid, jassid, and whitefly with unfertilized treatment and decreased with an increase in the level of K fertilizer.

CONCLUSION

Results revealed that the foliar application and seed application of gibberellic acid significantly affected both growth parameters and yield parameters in potato except disease and pest incidence parameters. Maximum tuber yield was recorded under G_3 (181.20 q ha^{-1}) and G_2 (176.27 q ha^{-1}) treatments as compared to control (162.86 q ha^{-1}). Both 100% RDF and 75% recommended dose of potassium + K-biofertilizer is recommended for higher tuber yield and disease management under Amritsar conditions. B: C ratio of both G_2 and G_3 (1.20 or 1.28) and K_3 or K_2 treatment (1.46 or 1.58) was higher than other treatments also. No interaction between GA_3 and IPM was found significant. Since this conclusion is based on one-year data, the repetition of the experiment for one more year along with multi-location trials is suggested.

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