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Research Paper

Efficacy of plant growth regulators on productivity, quality and profitability of berseem (*Trifolium alexandrium*)

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ABSTRACT

A field experiment was conducted during the winter (*Rabi*) season of 2018–19 and 2019–20 at Agronomy Research Farm of the Chaudhary Charan Singh Haryana, Agricultural University, Hisar, Haryana, for evaluating various plant-growth regulating chemicals on quality-seed production of berseem or Egyptian clover (*Trifolium alexandrium* L.). The experiment was laid out in a randomized block design, replicated thrice with 8 foliar spray treatments, viz.; T_1, control; T_2, 2 sprays of water at weekly interval, starting from flower initiation; T_3, 2 sprays of potassium nitrate @ 2% at weekly interval; T_4, 1 spray of salicylic acid @ 75 ppm; T_5, 2 sprays of salicylic acid @ 75 ppm at weekly interval; T_6, 1 spray of potassium nitrate @ 2% followed by 1 spray of salicylic acid @ 75 ppm after 1 week interval; T_7, 2 sprays of potassium nitrate @ 2% alternatively sprayed with 2 sprays of salicylic acid @ 75 ppm; and T_8, 1 spray of cytokinins @ 50 ppm, applied at flower-initiation stage. The results revealed that, significantly higher yield attributes [capsules/m^2 (304), seeds/capsule (50.5), seed weight/5 capsules (0.63 g), 1,000 seed weight (3.97 g)] and seed yield (4.45 q/ha) of berseem were recorded under T_7 (2 sprays of potassium nitrate @ 2% alternatively sprayed with 2 sprays of salicylic acid @ 75 ppm) which was followed by (*fb*) T_6, (1 spray of potassium nitrate @ 2% *fb* 1 spray of salicylic acid @ 75 ppm alternatively at weekly interval). Thus, application of 2 sprays of potassium nitrate @ 2% alternatively sprayed with 2 sprays of salicylic acid @ 75 ppm at flowering stage may be recommended to farmers for getting sufficient green fodder in addition to higher recovery of quality seed in profitable manner from dual-purpose berseem.

Key words: Berseem, Plant-growth regulators, Profitability, Quality, Yield

Berseem or Egyptian clover is one of the most important leguminous forages crop, popularly known as king of fodder crops for irrigated condition of northern India. Among the berseem-growing countries, India is having highest area of around 2.0 million ha. However, India faces acute shortage of green fodder for 536.0 million livestock population (20th livestock census) and to feed this much of animal population, fodder production is being done in merely 5% of gross cropped area which results in deficit of about 35% in green-fodder supply (Malhi *et al.,* 2020). India imports about 10,000 tonnes berseem seed annually, resulting in huge loss to foreign exchequer. The commercial seed production is less successful in India due to the more demand for fodder during the lean period and thus, less opportunity for seed production.

The seed yield could be enhanced through adoption of improved agronomic practices such as cutting management (numbers and time of last fodder cut), irrigation scheduling and foliar spray of chemicals (nutrients and plant-growth regulators) after the last forage cut. Plant-growth regulators (PGR's) such as salicylic acid, potassium nitrate and cytokinins are known to enhance the source sink relationship and stimulate the translocation of photo-assimilates, thereby inducing long-term thermo-tolerance, which helps in effective flower formation, fruit and seed development and ultimately enhance the productivity of the number of crops (Rab and Haq, 2012). Salicylic acid retards ethylene synthesis, stimulates photosynthetic machinery, increases the chlorophyll content and is reported to increase the seed yield in legumes under high temperature stress conditions (Hayat *et al.,* 2010). Potassium nitrate (KNO_3) plays an important role in the adaptation of cells to abiotic stresses through their effect on water uptake, root growth, maintenance of turgour pressure and thereby can help in normal

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functioning of plants (Rani *et al*., 2017). Cytokinins promotes axillary bud out growth (Verma *et al*., 2019). The foliar application of these plant-growth regulators at flower-initiation stage is known to induce more flowering as well as seed setting and increases the seed production in crops. Since, meager information is available about the influence of plant-growth regulator sprays on seed yield and quality of berseem in India, the present experiment was carried out with the aim of enhancing yield and quality of berseem seed using chemicals and plant-growth regulators.

A field experiment was conducted at Agronomy Research Farm of the Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India (29°10°N, 75°46°E and 215.2 m altitude). The soil was sandy loam, having slightly alkaline reaction (7.6), low organic carbon (0.39%), poor in available nitrogen (194 kg/ha), medium in available phosphorus (12.5 kg/ha) and rich in available potassium (258 kg/ha). Experimental site falls under semi-arid and sub-tropical climate with hot, dry and desiccating winds during the summer and severe cold during the winter season. The mean maximum/minimum temperature, morning/evening relative humidity, wind speed, bright sun shine hours, PAN evaporation, total rainy days and total rainfall during crop duration from last fodder cut up to harvesting of crop of 2018–19 and 2019–20 were 38.3/20.5°C, 63.6/26.1%, 5.2 km/h, 8.3, 7.2, 8 and 75.3 mm and 35.3/19.7°C,71.9/34.8%, 5.4 km/h, 7.9, 6.1, 6 and 68.7 mm respectively. The experiment was laid out in randomized block design, replicated thrice with 8 foliar spray treatments, viz. T_1, control; T_2, 2 water sprays at weekly interval starting from flower initiation; T_3, 2 sprays of potassium nitrate @ 2% at weekly interval; T_4, 1 spray of salicylic acid @ 75 ppm; T_5, 2 sprays of salicylic acid @ 75 ppm at weekly interval; T_6, 1 spray of potassium nitrate @ 2% followed by 1 spray of salicylic acid @ 75 ppm after 1 week interval; T_7, 2 sprays of potassium nitrate @ 2% alternatively sprayed with 2 sprays of salicylic acid @ 75 ppm; and T_8, 1 spray of cytokinins @ 50 ppm, applied at flower initiation. Berseem variety 'HB 1' was sown @ 20 kg seed/ha in October, with application of 25 kg N + 70 kg P/ha. Crop was grown with all recommended packages and practices during both the years. Three fodder cuttings were taken with sickle from the net plot area (5.00 m × 3.50 m). First, second and third fodder cuttings were taken at 62, 90 and 124 and 67, 88 and 110 days after sowing in the first and the second year of study respectively. For assessing the quality parameters (germination percentage, seedling dry weight, seedling length, seedling vigour index I and II), 100 sterilized seeds were subjected for germination at 20–25°C in BOD incubator for a week and then, the germinated seeds were counted for germination per cent, seedling length and dry weight. Parameters of economics of different treatments were calculated as per prevailing market rate of input-output. To find out the most profitable treatment, economics of different treatments were worked out in terms of net returns by taking into account the cost of cultivation and gross returns of the crop. Treatment-wise benefit : cost (B : C) was calculated to ascertain economic viability. All the experimental data for various characters were statistically analysed by the method of analysis of variance (ANOVA) as described by Panse and Sukhatme (1985) using OPSTAT software.

Results showed that, application of potassium nitrate (2%) followed by (*fb*) salicylic acid (75 ppm) foliar sprayed alternatively at weekly interval through double spray resulted significantly higher test weight, plant height, capsules/m^2 and seeds/capsule, followed by potassium nitrate @ 2% salicylic (75 ppm) foliar sprayed alternatively at weekly interval (Table 1). The test weight was noted 19.2, 20.3, 26.8 and 33.7% higher under treatment potassium nitrate @ 2% salicylic (75 ppm) foliar sprayed alternatively at weekly interval through double spray as compared to the other treatments respectively. The enhanced test weight with the spray of potassium nitrate and salicylic acid might be owing to the enhanced photosynthesis rate and better photosynthate translocation efficiency (Kumar *et al.,* 2013). Foliar spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) done alternatively at weekly interval through 2-time or 1-time spray and single spray of cytokinins (50 ppm) recorded at par plant height (85.7 to 87.7 cm), being was 11.6 to 13.9% higher than the control. Significant increase in plant height under foliar spray of potassium nitrate (2%), salicylic acid (75 ppm) and cytokinin (50 ppm) may be owing to better cell-division, enzymic activity and water balance of different plant tissues which results in better crop-growth rate (Kumar and Sarlach, 2015). Foliar application of potassium nitrate (2%) *fb* salicylic acid (75 ppm) done alternatively at weekly interval through 2 sprays recorded significantly more capsules/m^2 (304.0) and seed weight/5 capsules (0.63 g) compared to all the treatments except single spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) at weekly interval and 2 sprays of salicylic acid (75 ppm). Capsules/m^2 and seed weight/5 capsules did not differ significantly among the control and 2 water sprays done at weekly interval. Potassium nitrate (2%) *fb* salicylic acid (75 ppm) foliar-applied alternatively at weekly interval through double spray resulted in significantly more capsules/m^2, 9.2, 11.2 and 19.8% higher and seed weight/5 capsules which were 26.0, 26.0 and 57.5% higher than 2 sprays of potassium nitrate (2%), 1 spray of cytokinins (50 ppm) and control treatment respectively. It might be owing to better fertilization, higher seed setting and better partitioning and translocation of

energy molecules to reproductive parts (Khan *et al.,* 2020). Among all yield attributes, seeds/capsule were found most significantly influenced parameter by all the treatments. Potassium nitrate (2%) *fb* salicylic acid (75 ppm) foliar-applied alternatively at weekly interval through double spray recorded significantly more seeds/capsule over all other treatments with a per cent increase of 29.8, 61.8, 57.3 and 110.4 over 2 sprays of salicylic acid (75 ppm), 2 sprays of potassium nitrate (2%) at weekly interval, 1 spray of cytokinins (50 ppm) and control treatment, respectively. Higher seeds/capsule under different chemical sprays might be attributed to better fertilization, optimum seed setting and proper seed filling during reproductive stage (Kumar and Sarlach, 2020).

Green fodder yield obtained from 3 cuttings was not affected significantly as the treatments were imposed on crop after cuttings at initiation of flowering (Table 1). Green fodder yield obtained under different treatments were almost similar with a statistical variation of 1.0 to 5.1% which might be due to non-significant variation of various resources over the experimental area. Application of 2 sprays of potassium nitrate (2%) *fb* salicylic acid (75 ppm) alternatively at weekly interval resulted significantly highest seed and biological yields (Table 1). The advantage for seed yield was 14.0, 9.1, 10.9 and 40.8% higher than treatment T_3, T_5, T_8 and T_1 respectively. Similarly, the advantage for biological yield was 15.0, 10.9, 14.2 and 24.0% higher than treatment T_3, T_5, T_8 and T_1 respectively. However, single spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) at weekly interval also realized high seed and biological yields which was slightly less but statistically at par with treatment application of 2 sprays of potassium nitrate (2%) *fb* salicylic acid (75 ppm) alternatively at weekly interval. Seed-yield advantage in application of 2 sprays of potassium nitrate (2%) *fb* salicylic acid (75 ppm) alternatively at weekly interval was to the tune of 1.00 to 33.7%, 3.0 to 19.8% and 13.9 to 110.4% higher with respect to test weight, capsules/m^2 and seeds/capsule, respectively, as compared to all the other treatments including the control. The superior performance of this treatment for biological and seed yields recovery may be attributed to the plant-growth regulation effect where ethylene production is inhibited that helps to increase chlorophyll content and photosynthetic activity in plants and reduces damage or injury to the cells by reduction in respiration activity during stress which, ultimately leads to better growth attributes including higher plant height, enhanced crop-growth rate and more dry-matter accumulation, enhanced translocation efficiency, better source to sink relationship, improved yield attributes higher seed setting and improved seed and biological yields (Kumar *et al.,* 2014).

Various treatments involving foliar spray of PGR chemicals and water including the control exerted non-significant influence on harvest index (%) of berseem (Table 1). However, 1 foliar spray of cytokinins @ 50 ppm resulted in higher percentage of harvest index which was closely followed by 1-time foliar spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) done alternatively at weekly interval and it was 18.4% higher than the control plot. The slight enhancement in harvest index with cytokinins might be owing to enhanced biomass partitioning and faster translocation of energy molecules to developing seeds during reproductive phase of life that enhanced ratio of seed yield with biological yield (Vijay *et al.,* 2017).

Foliar spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) done alternatively at weekly interval through 2-time spray, closely followed by single spray of same recorded significantly higher germination (%) than the other

Table 1. Effect of different chemical sprays on yield and yield attributes of dual-purpose berseem (2-year averaged data)

Treatment	Plant height (cm)	Capsules/ m^2	Seeds/ capsule	Seed weight/5 capsules (g)	1,000-seed weight (g)	Green fodder yield (q/ha)	Seed yield (q/ha)	Biological yield (q/ha)	Harvest index (%)
T_1	77.0	253.8	24.0	0.40	2.97	420.4	3.16	50.0	6.25
T_2	80.0	268.0	29.3	0.41	3.00	427.6	3.39	51.8	6.43
T_3	82.9	278.3	31.2	0.50	3.30	428.6	3.87	53.9	7.09
T_4	84.1	272.5	33.1	0.43	3.47	426.1	3.69	54.4	6.70
T_5	84.5	290.0	38.9	0.53	3.13	433.2	4.08	55.9	7.18
T_6	86.2	295.0	44.3	0.57	3.93	436.8	4.35	59.3	7.23
T_7	87.7	304.0	50.5	0.63	3.97	441.8	4.45	62.0	7.15
T_8	85.7	273.3	32.1	0.50	3.33	436.2	4.01	54.3	7.40
CD (P=0.05)	2.9	16.5	3.0	0.14	0.32	NS	0.36	3.8	NS

T_1, Control; T_2, 2 water sprays at weekly interval starting from flower initiation; T_3, 2 sprays of potassium nitrate @ 2% at weekly interval; T_4, 1 spray of salicylic acid @ 75 ppm; T_5, 2 sprays of salicylic acid @ 75 ppm at weekly interval; T_6, 1 spray of potassium nitrate @ 2% followed by 1 spray of salicylic acid @ 75 ppm after 1 week interval; T_7, 2 sprays of potassium nitrate @ 2% alternatively sprayed with 2 sprays of salicylic acid @ 75 ppm; and T_8, 1 spray of cytokinins @ 50 ppm

treatments, being 5.1, 5.7, 6.6 and 12.7% higher than 2 sprays of salicylic acid (75 ppm), 1 spray of cytokinins (50 ppm), 2 sprays of potassium nitrate (2%) at weekly interval and the control treatment respectively (Table 2). It might be owing to minimum number of abnormal, hard and dormant seeds per count in respective treatments which may be attributed to positive role of potassium nitrate, salicylic acid and other chemicals in seed (Rani *et al.,* 2017). Significantly least number of abnormal, hard and dormant seeds per count were reported with treatment having 2-time foliar spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) done alternatively at weekly interval, being 41.8, 35.7 and 46.5% lower than the control. Foliar spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) done alternatively at weekly interval through 2-time spray resulted in significantly higher seedling dry weight than all the treatments, being 21.6, 50.0, 60.7 and 87.5% higher than 2 sprays of salicylic acid (75 ppm), 1 spray of cytokinins (50 ppm), 2 sprays of potassium nitrate (2%) at weekly interval and control respectively. It might be attributed to positive role of potassium nitrate, salicylic acid and other chemicals in maintaining seed health (Kumar and Sarlach, 2020). Seedling length was affected non-significantly by different treatments. However, foliar spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) done alternatively at weekly interval through 2-time or 1-time spray ensued higher seedling length, with an increase of 10.4% over the control and water spray treatments. Foliar spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) done alternatively at weekly interval through 2-time spray recorded significantly higher seed Vigour Index I and seed Vigour Index II compared to all the other treatments except single spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) done alternatively at weekly interval and it was 13.2, 16.1, 19.6 and 38.4% higher in case of SVI I and 122.1, 136.1, 171.6 and 200.6% higher in case of SVI II than 2 sprays of salicylic acid (75 ppm), 1 of cytokinins (50 ppm), 2 of potassium nitrate (2%) at weekly interval and control treatment respectively. Higher SVI with salicylic acid and potassium nitrate spray might be owing to significantly higher germination percentage, seedling dry weight and length and enhanced translocation of photosynthates (Olaiya *et al.,* 2013).

Significant improvement in seed (58.4%) and biological (32.2%) yields was observed with 2 sprays of potassium nitrate (2%) *fb* salicylic acid (75 ppm) alternatively at weekly interval in 2019–20 compared to 2018–19 (Table 1). The increment of green fodder yield during 2018–19 was 38.3% higher than that of 2019–20 which might be owing to fact of favourable effect by optimum weather conditions for higher vegetative growth (Verma *et al*., 2019) and moreover, delay in the last cutting of fodder during the first year of study. All yield attributes except plant height and seeds/capsule were significantly at par in both the years, except test weight and seed weight/5 capsule were recorded higher during 2018–19 than 2019–20. Test weight and seed weight/5 capsules during 2019–20 were recorded with increase of 3.6 and 12.7%, respectively, over 2018–19. All seed-quality parameters except number of dormant seeds differed non-significantly between years of study. However, numerically higher seedling length and dry weight, dormant seeds and Vigour Index-I were recorded during 2019–20 compared to 2018–19. Significant improvement in gross returns (6.1%), net returns (21.8%) and benefit : cost ratio (6.5%) over 2018–19 was noticed with 2 sprays of potassium nitrate (2%) *fb* salicylic acid (75 ppm) alternatively at weekly interval during 2019–20. It might be owing to 58.4% higher seed during 2019–20 compared to 2018-19. Similar variations over years were also highlighted and reported by Bakheit

Table 2. Effect of different chemical sprays on seed quality of dual-purpose berseem (2-year averaged data)

Treatments	Germination (%)	Abnormal seeds	Hard seeds	Dormant seeds	Seedling dry weight (g)	Seedling length (cm)	Vigor Index I	Vigor Index II
T_1	65.3	8.6	12.6	14.6	0.024	9.6	598.7	1.50
T_2	66.3	8.0	12.1	14.5	0.027	9.6	631.5	1.54
T_3	69.0	7.0	11.6	13.8	0.028	10.0	692.9	1.73
T_4	68.3	7.3	11.7	14.1	0.027	10.0	664.8	1.66
T_5	70.0	6.4	11.0	13.0	0.037	10.3	731.8	2.03
T_6	72.6	6.6	9.8	12.1	0.039	10.6	777.8	3.14
T_7	73.6	5.0	8.1	7.8	0.045	10.6	829.2	4.51
T_8	69.6	6.6	11.6	13.6	0.030	10.3	713.6	1.91
CD (P=0.05)	3.4	1.2	1.8	3.5	0.005	NS	94.6	0.73

T_1, Control; T_2, 2 water sprays at weekly interval starting from flower initiation; T_3, 2 sprays of potassium nitrate @ 2% at weekly interval; T_4, 1 spray of salicylic acid @ 75 ppm; T_5, 2 sprays of salicylic acid @ 75 ppm at weekly interval; T_6, 1 spray of potassium nitrate @ 2% followed by 1 spray of salicylic acid @ 75 ppm after 1 week interval; T_7, 2 sprays of potassium nitrate @ 2% alternatively sprayed with 2 sprays of salicylic acid @ 75 ppm; and T_8, 1 spray of cytokinins @ 50 ppm

(2013) for the favourable effect of climatic conditions on yield and growth of berseem.

The highest and lowest variable cost and total cost were recorded with 2-time spray of potassium nitrate (2%) *fb* by salicylic acid (75 ppm) at weekly interval and control treatment respectively (Table 3). The maximum variable (₹52,733/ha) and total cost (₹107,156/ha) were recorded with 2-time spray of potassium nitrate (2%) *fb* by salicylic acid (75 ppm) at weekly interval, and the cost was assessed 28.7 and 12.3% higher over the control respectively. Gross returns recorded with foliar spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) done alternatively at weekly interval through 2-time or 1-time spray, 2 sprays of salicylic acid (75 ppm) and single spray of cytokinins (50 ppm) were found statistically at par. Significantly higher gross returns (₹156,347/ha) were registered with 2-time sprays of potassium nitrate (2%) *fb* by salicylic acid (75 ppm) at weekly interval were found 9.6 and 25.8% higher than the control. Similar trend of observation was noticed with net returns and benefit : cost (B : C) also. The realization of higher gross returns, net returns and B : C depends on the magnitude of economic yield produced (Gupta *et al.,* 2020). The higher value of these profitability parameters with 2-time spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) at weekly interval might be owing to the higher yield attributes which resulted in higher recovery of economic yield produced (Gupta *et al.,* 2018). One-time spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) at weekly interval closely followed by 1 spray of cytokinins (50 ppm) and 2 sprays of salicylic acid (75 ppm) at weekly interval resulted in significantly higher net returns (₹52,274/ha), being 31.6 and 80.8% and B : C (1.52) which was 10.1 and 80.8% higher than 2 sprays of potassium nitrate (2%) at weekly interval and control treatment respectively. Gross and net returns obtained in the control and water spray was found statically at par. It may be attributed to comparative variation in input and output levels and costs (Kumar *et al*., 2013).

Thus, the relative performance of various PGR chemicals inferred that the double as well as single foliar spray of potassium nitrate (2%) *fb* salicylic acid (75 ppm) applied alternatively at weekly interval at flower-initiation stage could be most profitable, since it realizes significantly higher seed yield (4.35 q/ha), net returns (₹52,274/ha), B : C (1.52), seed germination (72.6%), Seed Vigour Index I (777.8) and Seed Vigour Index II (43.6) over the control. Hence, 2 sprays of potassium nitrate (2%) with 2 sprays of salicylic acid (75 ppm) at flowering stage may be recommended to farmers for getting sufficient green fodder in addition to higher recovery of quality seed in profitable manner from dual-purpose berseem.

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Table 3. Effect of different chemical sprays on economic parameters of dual-purpose berseem (2-year averaged data)

Treatment	Variable cost ($\times 10^3$ ₹/ha)	Total cost ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit : cost
T_1	40.95	95.37	124.27	28.89	1.30
T_2	42.95	97.37	132.03	34.65	1.35
T_3	48.55	102.97	142.68	39.70	1.38
T_4	43.04	97.46	137.12	39.65	1.41
T_5	45.13	99.55	148.82	49.26	1.49
T_6	46.84	101.26	153.54	52.27	1.52
T_7	52.73	107.15	156.34	49.19	1.46
T_8	43.15	97.57	148.31	50.73	1.51
CD (P=0.05)	–	–	103.70	103.70	0.10

T_1, Control; T_2, 2 water sprays at weekly interval starting from flower initiation; T_3, 2 sprays of potassium nitrate @ 2% at weekly interval; T_4, 1 spray of salicylic acid @ 75 ppm; T_5, 2 sprays of salicylic acid @ 75 ppm at weekly interval; T_6, 1 spray of potassium nitrate @ 2% followed by 1 spray of salicylic acid @ 75 ppm after 1 week interval; T_7, 2 sprays of potassium nitrate @ 2% alternatively sprayed with 2 sprays of salicylic acid @ 75 ppm; and T_8, 1 spray of cytokinins @ 50 ppm

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