Studies on the effect of plant growth regulators and their application methods on growth, yield and quality attributes of potato (Solanum tuberosum L.) variety Kufri Pukhraj under agro-climatic conditions of Chhattisgarh plains

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Abstract
The present investigation entitled “Studies on the effect of plant growth regulators and their application methods on growth, yield and quality attributes of Potato (Solanum tuberosum L.) variety Kufri Pukhraj under agro-climatic conditions of Chhattisgarh plains.” was performed at Research Cum Instructional Farm, College of Agriculture, IGKV, Raipur (C.G), during the Rabi season 2018-19 under ACRPT. The experiment was carried out with Factorial RBD with fourteen treatment combinations consisting of two methods of application S (Seed treatment) and F (Foliar Spray application) and seven levels of plant growth regulators viz., T1 (Plain water), T2 (GA3-15 ppm), T3 (GA3-25 ppm), T4 (GA3-50 ppm), T5 (IBA-100 ppm), T6 (IBA-200 ppm) and T7: (IBA-250 ppm) were replicated three times. The method of PGRs application significantly influenced on all growth, yield and quality parameters. The method of PGRs application non-significantly differentiate plant height, number of shoot and dry weight of shoot per plant, harvesting index, specific gravity. The interaction effect of these two components recorded significant lesser days for plant emergence under ST1(19 days), higher plant emergence percentage under ST1 (95.11%), maximum height of plant at 90 DAP under ST4 (61.78), maximum number of shoot under FT2 (13.13), maximum number of tuber per plant under FT2 (8.30), grade wise maximum tuber yield found that Grade B (50-75 g) tuber yield with FT2 of 9.17 kg/plot (10.19 t/ha). However, maximum total tuber yield was recorded with ST1that is (29.43 t/ha).

Keywords: Plant growth, application methods, growth, yield, Solanum tuberosum

Introduction
Potato (Solanum tuberosum L.) is one of the solanaceous vegetable crops which is most important in India. It belongs to family solanaceae having chromosome number 2n = 4x = 48. India is the world’s third largest potato producing nation. In India, potato occupies 21.79 million hectares area with 486.05 million hectares production and 22.30 ton/ha productivity (Anonymous, 2017). In Chhattisgarh, 44,202 hectares area is under potato cultivation with 6,80,523 metric tones production and 16.93 tones/ha productivity (Anonymous, 2017). Its tuber has multifarious use in home consumption as well as in processing industries. This crop is of significant economic importance in Chhattisgarh where it is cultivated mainly in rabi season in plain areas. In hilly area of Chhattisgarh i.e. Mainpat, it is cultivated in both rabi and kharif season. Potato brings economic returns to farmers within short period of time. Since the winters in plain areas of Chhattisgarh are of short period and early varieties fit well for cultivation. It is one of the staple food crops which occupy 4th rank after rice, wheat and maize. Potato ranks 2nd position in production (tons) after China. Potato is a extremely nutritious and readily digestible food crop. It includes carbohydrate, proteins, minerals, vitamins and other nutritional fibers. A potato tuber contains 80 percent water and 20 percent dry matter consisting of edible protein (2.8 g), starch (16.3 g), total sugar (0.6 g), crude fiber (0.5 g), fat (0.14 g), carbohydrate (22.6 g), vitamin C (25 mg), mineral (0.9 g), calcium (7.7 mg), iron (0.75 mg), ash (1-1.5 percent), anlylose (22-25 percent) and glycoalkaloids (< 1 mg) per 100 g of fresh anti-nutritional weight.
The significant element of potato tuber is starch, which accounts for about 70 percent of the total solids. Potato has increased dry matter production ability, which is approximately 47.6 kg / hectare / day. Potato generates the largest protein per unit region similar to egg and milk protein and superior in dietary quality to other vegetables, cereals and pulse proteins.

It is a short-lived crop capable of generating the greatest quantity of food per unit region and time. Being versatile in adaptability, it offers flexibility in harvesting with greater yields. Among several constraints in potato production, the temperature and photoperiods are major climatic factors affecting tuber yield and quality. The productivity of early potato varieties is lower due to short duration; moreover, under short periods of winters, there is lower productivity of potato in Chhattisgarh plains. The crop deserves attention with regards to development of suitable agronomic practices particularly for early and short duration potato varieties which are mainly cultivated in plain areas of Chhattisgarh. The roles of plant growth regulators under varying day length and temperature condition in potato has been reported by several workers through improvement in source and sink relationship thereby improving tuber yield and quality attribute. (Sillu et al., 2012; Pamukuntala et al., 2018) [3, 2]. Effect of PGR like gibberellic acid on plant growth, stoln development, tuberization and plant yield under varying photoperiods have been reported by Agrawal et al., 1983 [4]. It is reported that gibberellic acid 50 ppm to 400 ppm enhanced shoot emergence, tuber sprouting, number of leaves and marketable tuber yields. (Khurana and Pandita, 1987; Bhatia et al., 1992; Pamukuntala et al., 2018; Kumar et al., 2012; Javanmardi et al., 2017) [8, 5, 2, 7, 6].

Material and Methods

The present investigation entitled “Studies on the effect of plant growth regulators and their application methods on growth, yield and quality attributes of Potato (Solanum tuberosum L.) variety Kufri Pukhraj under agro-climatic conditions of Chhattisgarh plains.” was performed at Research Cum Instructional Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G), during the 2018-19 rabi season under All India Coordinated Potato Research Project.

The planting material (seed tubers) of potato variety Kufri Pukhraj was obtained from AICRP Potato, Department of Vegetable Science, IGKV, Raipur (C.G.). The plant growth regulators i.e., GA3 and IBA were used at different concentrations by using different methods of application i.e., seed treatment before planting and foliar sprays (at 30 and 60 DAP). The details of treatments and their different combinations comprising of application methods and foliar spray treatments at different concentrations are given in the Table 1.

| S. No | Methods of Application | Notation          | Details               |
|------|------------------------|-------------------|-----------------------|
| 1.   |                        | ST1               | Control (Plain water) |
| 2.   |                        | ST2               | GA3 (Gibberellic acid)15 ppm |
| 3.   |                        | ST3               | GA3 (Gibberellic acid) 25 ppm |
| 4.   |                        | ST4               | GA3 (Gibberellic acid) 50 ppm |
| 5.   |                        | ST5               | IBA (Indole Butyric Acid) 100 ppm. |
| 6.   |                        | ST6               | IBA (Indole Butyric Acid) 200 ppm. |
| 7.   |                        | ST7               | IBA (Indole Butyric Acid) 250 ppm. |
| 8.   |                        | FT1               | Control (Plain water) |
| 9.   |                        | FT2               | GA3 (Gibberellic acid) 15 ppm |
| 10.  |                        | FT3               | GA3 (Gibberellic acid) 25 ppm |
| 11.  |                        | FT4               | GA3 (Gibberellic acid) 50 ppm |
| 12.  |                        | FT5               | IBA (Indole Butyric Acid) 100 ppm. |
| 13.  |                        | FT6               | IBA (Indole Butyric Acid) 200 ppm. |
| 14.  |                        | FT7               | IBA (Indole Butyric Acid) 250 ppm. |

Table 1: Treatment Details

Seed potato tuber treatment at time of planting.
**Foliar spray at 30 and 60 days after planting (DAP).**

Result and Discussion

Growth attributes

Different growth attributes of potato namely days for plant emergence and emergence per cent at 30 days after planting and plant height, number of shoots per plant and number of compound leaves per plant were recorded. The all growth attributes was statistically analysed and results were presented in table 2 and 3.

In general, among plant growth regulators Giberrellic acid at all concentrations (T2, T3 and T4) showed minimum days to plant emergence over control treatment (T1), which took more number of days for plant emergence (24.5). The results were significantly different with respect to different plant growth regulators (PGR). The highest emergence percentage (92.89%) was observed in T3 (GA3 25ppm) followed by its lower concentration that is T2 (GA3 25ppm). The highest plant height (61.47 cm) was observed in T4 (GA3 50ppm) followed by concentration of IBA (60.65 cm) observed in T3 (IBA 250ppm). This increase in plant height might be due to the fact that the stimulatory effect of GA3 on plant height due to cell elongation and rapid cell division in growing portion, there are number of reports showing that gibberelins promote growth of intact plants. The results observed in this investigation for plant height are similar to the findings of Naeem et al. (2006) [10], Chovatia et al. (2014) [9], Sillu et al. (2012) [9]. The highest number of shoot per plant (13) was observed in T3 (GA3 25ppm) followed by its lower concentration that is T2 (GA3 15ppm) i.e. (12.17). The highest number of compound leaves per plant (109.1) was observed in T3 (GA3 25ppm) followed by its lower concentration that is T3 (GA3 15ppm) followed by (98.9) at its lower concentration that is T3 (GA3 25ppm) higher. Among plant growth regulators IBA at concentrations of 100ppm T3 showed maximum (338.60 g) fresh weight of shoots per plant which was followed by (298.75 g) in (GA3 50ppm). Among plant growth regulators, IBA at concentrations of 100ppm showed maximum (276.20 g) dry weight of shoots per plant which was followed by (246.25g) in T3 (GA3 50ppm).
Yield attributes

Different yield attributes of potato namely number of tubers plant\(^{-1}\), grade wise number of tuber plot\(^{-1}\), grade wise number of tuber hectare\(^{-1}\), grade wise numbers of tuber (% by number), grade wise tuber yield plot\(^{-1}\), grade wise tuber yield hectare\(^{-1}\), grade wise tuber yield (% by weight), tuber yield plot\(^{-1}\)(Kg), total tuber yield (Kg/ha), fresh weight of tuber plant\(^{-1}\), dry weight of tuber plant\(^{-1}\) (g), were recorded at harvest and results are presented in table 4 to 7.

The highest number of tubers per plant (7.93) was recorded in T\(_5\) (IBA 250 ppm) followed by its lower dose (7.90 g in T\(_7\) (IBA 250 ppm)). Among plant growth regulators, IBA at concentrations of 200 ppm showed maximum (266.92 g) fresh weight of tuber per plant which was followed by 259.80 g in T\(_3\) (IBA 250 ppm). Among plant growth regulators, IBA at concentrations of 200ppm showed maximum (337.81 g) fresh weight of tuber per plant which was followed by 320.30g in T\(_5\) (IBA250ppm). Among plant growth regulators, IBA at concentrations of 200ppm showed maximum (266.92 g) dry weight of tuber per plant which was followed by 259.80 g in T\(_7\) (IBA 250ppm). Among plant growth regulators, IBA at concentrations of 200ppm showed maximum (57.92 g) average weight of tuber which was followed by 53.96 g in T\(_5\) i.e. GA\(_3\)50 ppm. All the concentrations of IBA i.e. 100, 200 and 250 ppm produced greater number of Grade A tubers being maximum (92.53) at 200 ppm followed by 87.72 at lower dose (100ppm). The maximum (15.19) being in IBA 200ppm (T\(_5\)) followed by its lower doses (T\(_3\)) i.e. 14.05 Control treatment (T\(_1\)) produced minimum A grade percentage of tubers.

It was revealed from data that the grade wise tuber yield per plot was observed maximum in treatment T\(_6\) (IBA200ppm) of Grade B followed by GA\(_3\)50ppm (T\(_4\)) i.e. 34.45 of grade B. It was revealed from data that the tuber yield per hectare was noted maximum (9794.25 kg) in treatment T\(_6\) (IBA200ppm) of Grade B followed by the Grade C (9112.05kg) in same treatment. Plant growth regulators significantly inspired grade B to the percentage and the maximum (34.80) being in IBA 200ppm (T\(_6\)) followed by GA\(_3\) 50ppm (T\(_4\)) i.e. 34.45 of grade B. It was revealed from data that the tuber yield per plot was observed maximum in treatment T\(_6\) (IBA200ppm) i.e. (25.33kg) followed by 24.02 kg in treatment T\(_7\) (IBA 250ppm).

Maximum tuber yield per hectare (29434.25 kg) was noted in treatment combinations of foliar spray application (F) and IBA 200ppm (FT\(_6\)) and followed by (FT\(_7\)) i.e.,(28131.85).

Table 2: Effects of PGR’s on Days for Plant Emergence, Emergence % and Plant height, Number of Shoots and Compound leaves at 50, 75 and 90 DAP

| Treatments | Days for Plant Emergence | Emergence percentage (%) | Plant height (cm) | Number of shoots/Plant | Number of compound leaves /Plant |
|---|---|---|---|---|---|
| Methods | S | Seed treatment | 21.43 | 91.87 | 57.48 | 11.00 | 89.68 | 0.73 | 0.93 | NA | 0.27 |
| F | Foliar spray | 24.29 | 90.54 | 57.43 | 10.86 | 92.66 |
| CD(P=0.05) | 0.25 | 0.32 | 0.16 | 0.16 | 0.09 |
| Treatments | T\(_1\) | Plain water | 24.50 | 90.89 | 54.48 | 9.67 | 76.60 |
| T\(_2\) | GA\(_3\) (15 ppm) | 21.50 | 92.44 | 55.50 | 13.00 | 109.08 |
| T\(_3\) | GA\(_3\)(25ppm) | 22.00 | 92.89 | 57.42 | 12.17 | 98.86 |
| T\(_4\) | GA\(_3\) (50ppm) | 21.50 | 90.45 | 61.47 | 11.30 | 91.22 |
| T\(_5\) | IBA (100 ppm) | 24.00 | 90.22 | 55.61 | 9.83 | 86.29 |
| T\(_6\) | IBA (200 ppm) | 22.50 | 90.45 | 57.06 | 10.00 | 87.30 |
| T\(_7\) | IBA (250 ppm) | 24.00 | 91.11 | 60.66 | 10.50 | 88.87 |
| CD(P=0.05) | 0.46 | 0.60 | 0.29 | 0.31 | 0.17 |
| Methods x Treatments | ST\(_1\) | Plain water | 24.00 | 90.22 | 54.33 | 9.33 | 76.60 |
| ST\(_2\) | GA\(_3\) (15 ppm) | 20.00 | 94.67 | 55.80 | 12.87 | 107.27 |
| ST\(_3\) | GA\(_3\)(25ppm) | 19.00 | 95.11 | 58.00 | 11.97 | 96.87 |
| ST\(_4\) | GA\(_3\) (50ppm) | 20.00 | 90.67 | 61.78 | 11.67 | 90.90 |
| ST\(_5\) | IBA (100 ppm) | 22.00 | 90.22 | 55.82 | 10.43 | 83.64 |
| ST\(_6\) | IBA (200 ppm) | 22.00 | 90.67 | 55.91 | 10.37 | 84.80 |
| ST\(_7\) | IBA (250 ppm) | 23.00 | 91.56 | 60.72 | 10.67 | 87.73 |
| FT\(_1\) | plain water | 25.00 | 91.56 | 54.63 | 9.93 | 78.60 |
| FT\(_2\) | GA\(_3\) (15 ppm) | 24.00 | 90.22 | 55.20 | 13.13 | 110.88 |
| FT\(_3\) | GA\(_3\) (25ppm) | 25.00 | 90.67 | 56.84 | 12.30 | 100.85 |
| FT\(_4\) | GA\(_3\) (50ppm) | 23.00 | 90.22 | 61.16 | 11.00 | 91.57 |
| FT\(_5\) | IBA (100 ppm) | 26.00 | 90.22 | 55.40 | 9.50 | 88.93 |
| FT\(_6\) | IBA (200 ppm) | 24.00 | 90.22 | 58.20 | 9.76 | 89.80 |
| FT\(_7\) | IBA (250 ppm) | 25.00 | 90.67 | 60.60 | 10.36 | 90.00 |
| CD(P=0.05) | 0.66 | 0.84 | 0.42 | 0.43 | 0.25 |

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### Table 3: Effect of PGR’s on Fresh and Dry weight of shoots and tubers per plant (g) with dry matter content percentage.

| Treatments | Fresh weight per plant (g) | Dry weight per plant (g) | Dry matter content (%) |
|------------|----------------------------|--------------------------|------------------------|
|            | Shoot                     | Tuber                    | Shoot                  | Tuber                  | Shoot                  | Tuber                  |
| Methods    |                            |                          |                        |                        |                        |                        |
| S          | Seed treatment             | 251.44                   | 281.79                 | 208.93                 | 227.88                 | 16.86                  | 19.01                  |
| F          | Foliar spray               | 304.04                   | 298.61                 | 249.49                 | 235.60                 | 17.82                  | 21.01                  |
| SE(m)±     | 0.24                      | 0.57                     | 0.22                   | 0.57                   | 0.06                   | 0.04                   |
| CD(P=0.05) | 0.69                      | 1.66                     | 0.63                   | 1.66                   | 0.18                   | 0.11                   |

### Table 4: Effect of PGRs in number of tuber per plant and in total number of tuber per plot.

| Treatments | Number of tuber/plant | Total number of tuber /plot | Average weight of tuber |
|------------|-----------------------|-----------------------------|-------------------------|
| Methods    |                       |                             |                         |
| S          | Seed treatment        | 7.08                        | 579.11                  | 49.14                   |
| F          | Foliar spray          | 7.62                        | 590.25                  | 49.97                   |
| SE(m)±     | 0.06                  | 3.21                       | 0.45                    |                         |
| CD(P=0.05) | 0.17                  | 9.37                       | N/A                    |                         |

| Treatments | Number of tuber/plot | Total number of tuber /plot | Average weight of tuber |
|------------|----------------------|-----------------------------|-------------------------|
| T1         | Plain water          | 6.77                        | 535.01                  | 37.03                   |
| T2         | GA3 (15ppm)          | 7.45                        | 601.37                  | 45.92                   |
| T3         | GA3(25ppm)           | 7.07                        | 584.01                  | 49.85                   |
| T4         | GA3 (50ppm)          | 7.60                        | 592.00                  | 53.96                   |
| T5         | IBA (100 ppm)        | 7.52                        | 626.16                  | 53.80                   |
| T6         | IBA (200 ppm)        | 7.10                        | 585.36                  | 57.92                   |
| T7         | IBA (250 ppm)        | 7.93                        | 568.84                  | 48.38                   |
| SE(m)±     | 0.11                 | 6.00                       | 0.85                    |                         |
| CD(P=0.05) | 0.32                 | 17.53                      | 2.48                    |                         |

| Treatments | Number of tuber/plot | Total number of tuber /plot | Average weight of tuber |
|------------|----------------------|-----------------------------|-------------------------|
| T1         | Plain water          | 6.47                        | 529.68                  | 37.18                   |
| T2         | GA3 (15ppm)          | 7.37                        | 579.34                  | 43.73                   |
| T3         | GA3(25ppm)           | 7.00                        | 566.33                  | 52.19                   |
| T4         | GA3 (50ppm)          | 7.40                        | 592.33                  | 49.66                   |
| T5         | IBA (100 ppm)        | 6.93                        | 648.36                  | 54.84                   |
| T6         | IBA (200 ppm)        | 6.80                        | 597.33                  | 56.04                   |
| T7         | IBA (250 ppm)        | 7.57                        | 540.35                  | 50.31                   |
| FT1        | plain water          | 7.07                        | 540.33                  | 36.88                   |
| FT2        | GA3 (15ppm)          | 7.53                        | 623.39                  | 48.12                   |
| FT3        | GA3 (25ppm)          | 7.13                        | 601.69                  | 47.53                   |
| FT4        | GA3 (50ppm)          | 7.80                        | 591.67                  | 58.26                   |
| FT5        | IBA (100 ppm)        | 8.10                        | 603.95                  | 52.77                   |
| FT6        | IBA (200 ppm)        | 7.40                        | 573.39                  | 59.81                   |
| FT7        | IBA (250 ppm)        | 8.30                        | 597.33                  | 46.45                   |
Table 5: Effect of PGRs in number of tubers of different grades

| Treatments | Grade wise number of tuber per plot | Grade wise number of tuber (in thousands per hectare) | Grade wise number of tuber (% by number) |
|------------|-------------------------------------|------------------------------------------------------|----------------------------------------|
|            | Grade A | Grade B | Grade C | Grade D | Grade A | Grade B | Grade C | Grade D | Grade A | Grade B | Grade C | Grade D |
| Grades     | (>75g)  | (50-75g) | (25-50g) | (0-25g) | (>75g)  | (50-75g) | (25-50g) | (0-25g) | (>75g)  | (50-75g) | (25-50g) | (0-25g) |
| Methods    | S       | Seed treatment | 77.622 | 161.355 | 248.263 | 84.91 | 86.248 | 179.282 | 275.846 | 94.35 | 13.56 | 28.149 | 43.448 | 14.844 |
|            | F       | Foliar spray   | 85.817 | 185.975 | 245.805 | 83.56 | 93.553 | 206.637 | 273.117 | 92.73 | 14.238 | 30.963 | 49.013 | 13.888 |
|            | CD(P=0.05) |            | 0.537 | 0.381 | 0.326 | 0.406 | 0.297 | 0.424 | 0.362 | 0.451 | 0.084 | 0.154 | 0.309 | 0.109 |
|            | CD(P=0.05) |            | 1.571 | 1.115 | 0.952 | 1.187 | 1.745 | 1.24 | 1.059 | 1.318 | 0.245 | 0.449 | 0.904 | 0.318 |

Table 6: Effect of PGRs on tuber yield of different grades

| Treatments | Gradewise tuber yield kg/plot | Gradewise tuber yield kg/hectare | Gradewise tuber yield (% by weight) |
|------------|-------------------------------|----------------------------------|-------------------------------------|
|            | 75g | 50-75g | 25-50g | 0-25g | 75g | 50-75g | 25-50g | 0-25g | 75g | 50-75g | 25-50g | 0-25g |
| Methods    | S   | Seed treatment | 6.75 | 7.23 | 6.57 | 0.40 | 7501.66 | 8036.43 | 7479.60 | 447.00 | 31.97 | 34.23 | 31.78 | 1.89 |
|            | F   | Foliar spray   | 7.03 | 7.65 | 7.24 | 0.46 | 7815.72 | 8506.87 | 8048.70 | 512.63 | 31.45 | 34.18 | 32.34 | 2.03 |
|            | SE(m)± |            | 0.01 | 0.02 | 0.04 | 0.59 | 12.23 | 23.14 | 42.96 | 0.36 | 0.02 | 0.05 | 0.28 | 0.09 |
|            | CD(P=0.05) |            | 0.02 | 0.06 | 0.11 | 0.01 | 17.25 | 65.29 | 125.58 | 8.94 | 0.07 | 0.01 | 0.01 | 0.04 |
|            | CD(P=0.05) |            | 4.16 | 2.95 | 2.52 | 3.14 | 4.62 | 3.28 | 2.8 | 3.49 | 0.65 | 1.19 | 2.39 | 0.84 |

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Conclusion

The results obtained during the present investigation reveals that the effective concentration of undertaken plant growth regulators and application method can be used to improve the growth and yield parameters of potato. In the view of the results obtained from this investigation, it could be concluded that the growth parameters were positively influenced by seed treatment of GA3 (at all concentration). However, yield parameters were positively influenced by foliar treatment of IBA 200ppm.

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Table 7: Effect of PGR on total tuber yield

| Treatments | Total yield /Plot (Kg) | Total yield /ha (Kg/ha) |
|------------|------------------------|------------------------|
| **Methods** |                        |                        |
| S          | Seed treatment          |                        |
| F          | Foliar spray            |                        |
| CD(P=0.05) |                        |                        |
| **Treatments** |                      |                        |
| T1         | Plain water             |                        |
| T2         | GA3 (15ppm)            |                        |
| T3         | GA3(25ppm)             |                        |
| T4         | GA3 (50ppm)            |                        |
| T5         | IBA (100 ppm)          |                        |
| T6         | IBA (200 ppm)          |                        |
| T7         | IBA (250 ppm)          |                        |
| CD(P=0.05) |                        |                        |
| **Methods x Treatments** |              |                        |
| ST1        | Plain water             |                        |
| ST2        | GA3 (15ppm)            |                        |
| ST3        | GA3(25ppm)             |                        |
| ST4        | GA3 (50ppm)            |                        |
| ST5        | IBA (100 ppm)          |                        |
| ST6        | IBA (200 ppm)          |                        |
| ST7        | IBA (250 ppm)          |                        |
| CD(P=0.05) |                        |                        |

of nitrogen, sprout growth regulators and application method can be used to improve the growth and yield parameters of potato. In the view of the results obtained from this investigation, it could be concluded that the growth parameters were positively influenced by seed treatment of GA3 (at all concentration). However, yield parameters were positively influenced by foliar treatment of IBA 200ppm.

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