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Water stress mitigation in vegetable cowpea by plant growth regulators

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Abstract

Vegetables are the most susceptible group of crops to water stress, and consume more water through irrigation. Vegetable cowpea is an important protein catering vegetable, largely consumed in Kerala. Water stress is one of the major abiotic stresses that limit crop production and it hampers the physiological and biochemical mechanisms in plants, which lead to reduction in growth and yield. A field experiment was conducted during summer season (January - March) to study the effect of exogenous application of plant growth regulators (PGRs) for mitigating water stress in vegetable cowpea variety *Kashi kanchan*. The treatments comprised of foliar spray of cycocel (CCC) @ 10 mg/L and 20 mg/L, salicylic acid (SA) and ascorbic acid (AA) each @ 1% and 2%, naphthalene acetic acid (NAA) @ 20 mg/L and 40 mg/L, brassinolide @ 0.5 mg/L and 1 mg/L, coconut water spray and water spray along with three controls treatments viz, farmers' practice (irrigation at 2 days interval), irrigation at 5 days interval, and irrigation at 5 days interval with no irrigation during water stress imposed period. Results showed that foliar application of plant growth regulators during water stress imposed period resulted in an increased pod yield, stover yield and dry matter production compared to no treatment. Salicylic acid @ 2% also recorded the highest relative leaf water content and total chlorophyll content. Among the foliar applied plant growth regulators, salicylic acid @ 2% and NAA @ 40 ppm were superior in terms of pod yield and stover yield respectively. The present study revealed that foliar application of salicylic acid @ 2% or NAA @ 40 ppm can mitigate water stress in vegetable cowpea.

Keywords: Salicylic acid, naphthalene acetic acid, plant growth regulators, water stress, cowpea

Introduction

Water stress is a critical challenge in agricultural production, particularly for crops such as vegetable cowpea (*Vigna unguiculata*), which is highly sensitive to water availability as this leads to significant reductions in growth, yield, and quality of the crop. This issue is becoming important due to climate change and the growing scarcity of water resources, necessitating the development of effective strategies to mitigate the adverse effects of water stress. Therefore, for sustaining food security, high priority should be given to minimize the detrimental effects of water stress/drought. Phytohormones are well known to be involved in plant adaptation to water stress (Wang *et al.*, 2008) [26] and their exogenous application has been found to alleviate the negative effects of various abiotic stresses including drought (Fariduddin *et al.*, 2009) [9]. Plant growth regulators (PGRs) are naturally occurring or synthetic compounds that influence various physiological and biochemical processes in plants. Research works conducted in various crops revealed that exogenous application of plant growth regulators like cycocel (CCC) (Farooq and Bano, 2006) [10], salicylic acid (SA) (Azooz and Youssef, 2010) [4], ascorbic acid (AA) (Khalil *et al.*, 2010) [13], naphthalene acetic acid (NAA) (Parmer *et al.*, 2012) [17], brassinolide (Verma *et al.*, 2012) [25] and cytokinins (Huang, 2006) [12] were effective in mitigating the adverse effects of water stress and enhanced the crop stability to extreme water deficit conditions.

Vegetable cowpea is an important protein catering vegetable, largely consumed in Kerala. It is cultivated both as a main crop and as an intercrop with other crops. Being a non-season bound crop, it can be grown throughout the year even during summer season under irrigation, but water scarcity limits its area under cultivation. Moreover, limited research works have been conducted to investigate the potential benefits of exogenous application of plant growth regulators (PGRs)

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in cowpea grown under water stress conditions. So the present study was undertaken to evaluate the efficacy of exogenous application of certain plant growth regulators to mitigate water stress in cowpea, to find out an effective plant growth regulator for drought management and to assess the response of cowpea to these plant growth regulators.

Materials and Methods

A field experiment was conducted during summer season (January - March) in Agronomy farm, College of Agriculture, Vellanikkara (10° 31' N latitude and 76°13' E longitude) of Thrissur district, Kerala using the vegetable cowpea variety *Kashi Kanchan* (variety released from Indian Institute of Vegetable Research, Varanasi). It is a short duration (65-70days), photo-insensitive, bush type vegetable cowpea variety with dark green, soft, fleshy pods of 30-35 cm long, with a green pod yield of about 8-10 t/ha under favorable situations.

The treatments comprised of foliar spray of cycocel (CCC) @ 10 mg/L and 20 mg/L, salicylic acid (SA) and ascorbic acid (AA) each @ 1% and 2%, naphthalene acetic acid (NAA) @ 20 mg/L and 40 mg/L, brassinolide (Br.) @ 0.5 mg/L and 1 mg/L, coconut water (CW) spray and water spray (WS) which were compared with farmers' practice (irrigation at 2 days interval), irrigation at 5 days interval and irrigation at 5 days interval with no irrigation during water stress imposed period (3 controls). The soil of the experimental site was sandy clay loam (Order: Ultisol) having a bulk density of 1.58 Mg/m³, pH 5.4, organic carbon 1.2% (Walkley and Black method), available phosphorus (Bray-1 Extractant Ascorbic acid reductant method) and potassium (Neutral Normal Ammonium Acetate extractant flame photometry) 21.9 and 378.8 kg/ha respectively.

The selected area for the experiment was ploughed; stubbles were removed and levelled. At the time of final ploughing, farm yard manure @ 20 t/ha was applied uniformly and incorporated well to the soil. The experiment was laid out in Randomized Block Design with 15 treatments replicated thrice in mini plots of size 1.5 m x 1.5 m. All the plots were separated each other by a distance of one meter in order to prevent the seepage of irrigation water from one plot to other. Fertilizers were applied @ 20:30:10 kg N, P₂O₅ and K₂O/ha respectively in the form of urea, factomfos and muriate of potash as basal dose before sowing. The cowpea seeds were dibbled at a spacing of 30 cm x 30 cm in January.

After sowing the experimental plots were irrigated daily upto five days after sowing for uniform germination of seeds and thereafter all treatment plots other than farmers' practice and irrigation at 5 days interval were irrigated at 5 days interval upto 15 DAS with skipping irrigation at 20, 25, 30 and 35 DAS to impose water stress. Irrigation was given at 2cm depth. Plant growth regulators, coconut water and water were sprayed at 25 DAS (10 days after imposing water stress). The spray fluid used was 500L/ha. There was no rainfall during the entire crop period. The average maximum and minimum temperature was 34.8 °C and 23.4 °C respectively and the average wind speed was 5.1km/hr (Table 1) Biometric observations, yield attributes and yield, total dry matter production and physiological observations were recorded from randomly selected observation plants. Observations on physiological parameters were recorded 10 days after the exogenous application of PGRs, coconut water and water. Relative leaf water content (RLWC) was estimated using the method suggested by Barrs (1986) [6]. Fresh fully opened leaves from top were taken and cut into small pieces. Then a known weight from each sample was taken and immediately weighed to get the fresh weight and hydrated to full

turgidity for four hours. After four hours, the samples were taken out, wiped off the surface moisture quickly and lightly with filter paper, and immediately weighed to obtain fully turgid weight. The samples were oven dried at 80 °C for 24 hours and weighed to determine dry weight.

$$RLWC = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

Chlorophyll content of leaves was calculated using the formula suggested by Yoshida *et al.* (1972) [28]. Fresh leaf samples were collected from each plot. Then a known weight from each sample was taken and the chlorophyll was extracted using Dimethyl Sulphoxide (DMSO). Then the intensity of colour was read using Spectronic 20 spectrophotometer at 663nm and 645nm.

Results and Discussion

General growth and yield of the crop was less than normal due to the absence of rainfall and extreme dry condition prevailed during the entire crop growth period. The most noticeable morphological feature affected by water stress is the plant height. Though the variety attains a height of 50-60 cm under normal conditions, water stress decreased it to the range of 10-13 cm at 60 days after sowing (DAS) (Table 2). Though plant height was not significantly influenced by various treatments at any stage of observation (15, 30, 45 and 60DAS), at 60 days after sowing (DAS), the treatments which received spraying of either plant growth regulators (except brassinolide 1ppm) or coconut water or water during the water stress imposed period resulted in an increasing trend of plant height from 1 to 25 per cent compared to that which received no treatment during the period.

Number of leaves of cowpea plants was not significantly influenced by any of the treatments at 15 and 30 DAS. However, at 45 DAS, plants irrigated on alternate days (farmer's practice) recorded the highest leaf number of 15.3 which was on par with those irrigated at 5 days interval (12.6). Among the PGRs, NAA 40 ppm recorded the highest number of leaves per plant followed by water spray and salicylic acid 2%. At 60 DAS, there was a decline in the number of leaves per plant in farmers practice and irrigation at 5 days interval due to attainment of early maturity. By 60 DAS, the treatments which received either PGRs (except ascorbic acid 2%) or water during the water stress imposed period resulted in an increasing trend in number of leaves from 7 to 38 per cent compared to that which received no treatment during the period. Among the PGRs, NAA 40 ppm and salicylic acid 2% were found to be on par with farmer's practice which recorded the highest number of leaves (Table 2). This showed the favourable influence of the treatments on the growth of vegetable cowpea during the water stressed period. The lower growth characters in absolute control are due to the adverse effect of water deficit on cell division, cell enlargement and differentiation. Moreover, exposure of plants to water stress affects stomatal opening and closing which in turn reduce the transpiration rate thereby reducing the nutrient absorption and their efficient utilization by the crop.

A progressive increase in leaf area index was noticed up to 60 DAS in all treatments except in farmers practice and irrigation at 5 days interval. The decline in leaf area index in plots irrigated on alternate days and at 5 days interval at 60 DAS was due to the leaf fall as a result of attainment of early maturity. In general, all the treatments recorded significantly higher leaf area

index compared to absolute control at all of stages of observation (20, 40, & 60 DAS). Leaf area index at 20 DAS did not show much variation among the treatments. However at 40 DAS, leaf area index varied significantly among the treatments and it was highest in farmers practice followed by the treatment irrigated at 5 days interval. Plots sprayed with water during the stress imposed period recorded leaf area index on par with the treatment irrigated at 5 days interval followed by brassinolide 0.5%, salicylic acid 1 and 2%, NAA 40 ppm, and CCC 10 ppm. At 60 DAS, farmers practice recorded the highest leaf area index and it was found to be on par with salicylic acid 1 and 2%, NAA 40 ppm and water spray (Table 2). The higher number of leaves and leaf area index noticed in NAA 40 ppm and salicylic acid 2% at 60 DAS can be due to their positive effect on source sink relationship (Upadhyay and Ranjan, 2015) [24]. The positive influence of salicylic acid on leaf area index of cowpea (Afshari *et al.*, 2013) [1], common bean (Sadeghipour and Aghaei, 2012) [18] and that of NAA on plant height, number of leaves per plant, number of branches per plant and leaf area of soybean was reported by Deotale *et al.* (1998) [8].

No branches were observed at 15 DAS. At 30 DAS, branches were noted only in plots irrigated on alternate days (farmer's practice) and at 5 days interval and in plots sprayed with salicylic acid 2%. None of the treatments could bring about any significant influence on number of branches of cowpea plants at 30 and 60 DAS. However at 45 DAS, significantly higher number of branches was noticed in plots irrigated on alternate days (farmer's practice) and at 5 days interval. At 60 DAS, the treatments which received spraying of either plant growth regulators (except CCC 10 ppm, ascorbic acid 1% and brassinolide 1ppm) or water during the water stress imposed period resulted in an increasing trend of number of branches from 9.5 to 38 per cent compared to that which received no treatment during the period (Table 2).

Plants acquire water from soil only through roots. So root length, its density and proliferation are important to overcome water stress. All the treatments recorded significantly higher root length compared to absolute control. Highest root length of 19.8 cm was observed in farmers' practice which was on par with salicylic acid 2% (17.3 cm) (Table 2). Application of PGRs resulted in an increase in root length ranging from 23 to 45 per cent compared to absolute control which received no treatment during the water stress period. Water shortage forced the plants to increase the root length so as to extract more water from deeper layers of soil. All these showed the positive effect of salicylic acid 2%, NAA 40 ppm and water spray on the growth of cowpea plants grown under water stress situation. Increased root length in garlic with application of salicylic acid under water stress was also reported by Bideshki *et al.* (2013) [7]. Root shoot ratio of cowpea plants were not significantly influenced by various treatments. However, numerically higher root shoot ratio was recorded by salicylic acid 2% and NAA 40 ppm and the lowest ratio by absolute control. Even though a higher root length was obtained in plants irrigated on alternate days (farmer's practice) and at 5 days interval, a lower root shoot ratio was obtained in those treatments as these treatments produced a higher shoot growth also.

Under favorable conditions, the variety *Kashi Kanchan* flowers in 40-45 DAS. All the water stress imposed treatments showed a slight delay of one to four days (45 to 49 DAS) in attaining 50 per cent flowering compared to those received irrigation on alternate days (farmer's practice) and at 5 days interval which initiated flowering at 44 DAS. This can be due to the delay in attaining sufficient vegetative growth before flowering as a

result of imposed water stress as reported by French (2012) [11] in faba bean. Comparatively early flowering (44 DAS) was noted in farmer's practice and in treatments that received irrigation at 5 days interval. Salicylic acid 2% and water spray resulted in 50 per cent flowering at 45 DAS.

Highest chlorophyll content and relative leaf water content (RLWC) was recorded by farmers practice due to non-exposure of cowpea plants to water stress whereas the lowest by absolute control as a result of the impact of extreme water stress experienced by the plants. Among PGRs, salicylic acid recorded the highest chlorophyll content and it was on par with irrigation at 5 days interval and coconut water. In the case of RLWC, salicylic acid 2% recorded the highest value (78% over absolute control) which was on par with the treatment irrigated at 5 days interval, foliar spray of coconut water, ascorbic acid 1%, CCC 20 ppm, water and NAA 40 ppm (Table 3). Exogenous application of either PGRs, or coconut water or water during the water stress imposed period could increase the chlorophyll content to the tune of 5 to 53 per cent and relative leaf water content to the range of 2 to 78 per cent compared to no treatment during the period. The decrease in chlorophyll under drought stress is mainly the result of damage to chloroplasts caused by reactive oxygen species (Smirnov, 1995) [21]. Effect of drought stress on reduction of total chlorophyll content in cowpea was also reported by Singh and Raja Reddy (2011) [19] and in mung bean by Thalooh *et al.* (2006) [23]. Favourable influence of exogenous application of salicylic acid, on chlorophyll content and relative leaf water content in cowpea plants was reported by Afshari *et al.* (2013) [1].

General yield of crop was low due to effect of extreme dry condition prevailed during the crop period on vegetative growth, flowering and yield attributes. The variety *Kashi Kanchan* has a potential to produce about 40-45 pods/plant under favourable climatic conditions. Highest number of pods per plant was recorded by farmers' practice which was irrigated on alternate days followed by those irrigated at 5 days interval and the lowest by absolute control which received no treatment during water stress imposed period. Exogenous application of salicylic acid 2%, recorded the highest pod number per plant even though it was on par with all other PGRs. Under favourable condition pod length of variety *Kashi Kanchan* ranges from 30-35 cm. Due to extreme dry condition prevailed during crop season, the pod length recorded by various treatments in the experiment ranged from 25 to 29 cm. The data showed that pod length of cowpea plants was not significantly influenced by exogenous application of any of the PGRs, coconut water or water. None of the treatments could influence the number of seeds per pod of cowpea plants. Pod weight of cowpea plants was not significantly influenced by exogenous application of any of the treatments. However, all the treatments showed an increasing trend in pod weight ranging from 27 to 43 per cent compared to absolute control. Among PGRs, salicylic acid 2% brought about 43 per cent increase in pod weight compared to no treatment during the water stress imposed period.

Pod yield was significantly influenced by various treatments. Highest pod yield was recorded by farmers' practice (3348 kg/ha) which received irrigation on alternate days. Among PGRs, salicylic acid 2% recorded the highest pod yield (2962 kg/ha) (Table 4) which was found to be on par with farmers practice, irrigation at 5 days interval, NAA 40 ppm and water spray (2777 kg/ha, 2774 kg/ha & 2755 kg/ha). This is due to the cumulative effect of comparatively higher yield attributes recorded by the above treatments. The favourable influence of salicylic acid on pod formation in soybean was reported by

Kumar *et al.* (1999)^[15] and on grain yield in corn by Yaghoubian *et al.* (2014)^[27]. Positive effect of NAA application on yield and yield attributes was reported by Aslam *et al.* (2010)^[3] in chick pea, Singh and Sharma (1982)^[20] in groundnut, Bai *et al.* (1987)^[15] in green gram and Khanzada *et al.* (2002)^[14] in soybean. The lowest pod yield was recorded by exogenous application of brassinolide 1ppm which was on par with absolute control and CCC10 ppm. Absolute control resulted in 153 per cent reduction in pod yield compared to farmers practice due to the impact of severe water stress on growth and yield attributes. In general, the crop recorded a lower stover yield due to less vegetative growth as a result of exposure of plants to unfavourable weather condition prevailed during the crop season. However, the stover yield of the crop was significantly influenced by various treatments. The highest stover yield was recorded by farmers practice (5097 kg/ha) and the treatment which received irrigation at 5 days interval (4768 kg/ha) and the lowest by absolute control (Table 4). Among PGRs, NAA 40 ppm recorded the highest stover yield (76 percent higher than that obtained in absolute control) followed by brassinolide 0.5ppm, salicylic acid 1%, NAA 20 ppm, CCC 20 ppm, water spray and salicylic acid 2%. Parmer *et al.* (2011)^[16] also reported the highest stover yield in green gram with foliar spray of NAA 40 ppm.

Dry matter accumulation in cowpea plants during the cropping period was significantly influenced by various treatments. Biomass reduction in cowpea due to water deficit was reported by Anyia and Herzog (2004)^[2]. Farmers practice recorded a significantly higher dry matter accumulation (1661.7 kg/ha) compared to all other treatments whereas absolute control recorded the lowest (644.9 kg/ha). All treatments which received spraying of either plant growth regulators or coconut water or water during the water stress imposed period could bring about 10 to 113 per cent increase in total dry matter production compared to no treatment during the crop period. Among the PGRs, NAA 40 ppm recorded the highest dry matter accumulation and it was on par with the treatment irrigated at 5 days interval. Aslam *et al.* (2010)^[3] reported that NAA application at 80 per cent water depletion could maintain the biological yield in chickpea.

Kashi Kanchan is a short duration vegetable cowpea variety, the duration of which is reported as 60-65 days. It was observed that the plants in treatments which received irrigation on alternate days and at 5 days interval attained final maturity (65 days) earlier than the remaining treatments. Absolute control as well as exogenous application of either PGRs, or coconut water or water extended the duration of the crop by one week (72 days)

without any variation among them. This can be due to the delay in attaining sufficient vegetative growth (physiological maturity) before flowering as a result of imposed water stress (Smith and Hamel, 2012)^[22].

Soil samples were collected from a depth of 20 cm at sowing and subsequently at 15 days interval till last harvest to estimate the soil moisture content (SMC). Soil moisture content in the field at sowing of cowpea seeds was 8.7 per cent. After sowing, uniform irrigation was given up to 5 days irrespective of treatments for germination and establishment of the crop. After 5 days, irrigation was given at 5 days interval till 15 DAS in all treatments except farmer's practice and the irrigated control, which was irrigated at alternate days and 5 days interval respectively. Further, irrigation was withheld up to 40DAS for imposing water stress in absolute control and in treatments which were sprayed with PGRs, coconut water and water. From 40 DAS, irrigation was restarted in the above treatments at 5 days interval.

In general, moisture status in the soil was very low during the entire crop period especially in water stress imposed treatments due to high evaporation caused by high wind speed and temperature. A gradual decline in soil moisture was observed in these treatments up to 30 DAS. However at 45 DAS, water stress release from these treatments resulted in a slight increase in soil moisture content and again from 60 DAS onwards it showed a slight progressive decline. Soil moisture status at all stages (15, 30, 45 and 60 DAS) was significantly influenced by various treatments and the highest soil moisture content was observed in farmers practice followed by the treatment irrigated at 5 days interval (except at 15 DAS) (Table 5).

At 15 DAS, since the crop was irrigated uniformly, soil moisture content ranged from 9 to 9.9 per cent among the treatments except in farmers practice. At 30 DAS (15 days after withholding irrigation), the soil moisture content in the water stress imposed treatments was 75.6 to 88.4 per cent less than that in farmers practice which were irrigated on alternate days. At 45 DAS, as the irrigation was restarted, soil moisture content increased to the range of 9 to 9.8 per cent from 6.9 to 7.4 per cent at 30 DAS in the water stress imposed treatments whereas at 60 DAS, water stress imposed treatments including absolute control showed a reduction in soil moisture content ranging from 8.1 to 8.9 per cent. At final harvest of the crop, a still reduction in soil moisture content was noticed in all treatments compared to that at 60 DAS and it ranged from 6.1 to 7.3 per cent which can be attributed to the stoppage of irrigation in all treatments on attainment of full maturity of the crop.

Table 1: Monthly mean weather data during the experiment period

Month	Maximum temperature (°C)	Minimum temperature (°C)	RH (%) morning	RH (%) evening	Rain Fall (mm)	Total evaporation (mm)	Sunshine hours	Wind speed (Km/hr)
January	32.9	23.0	66	36	0	171.3	277.6	6.9
February	34.7	22.9	75	37	0	145.0	240.8	4.5
March	36.7	24.2	76	34	0	191.5	264.2	3.9

Table 2: Effect of plant growth regulators on growth parameters of cowpea

Treatments	Plant height (cm)		No. of leaves		No. of branches			Root length (cm)	Leaf area index		Days to 50% flowering
	45 DAS	60 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS		40 DAS	60 DAS	
CCC 10	7.76	11.83	7.40	8.40	0.00	0.06	2.06	15.80	0.26	0.30	46.00
CCC 20	7.70	12.33	8.26	9.46	0.00	0.13	2.46	14.76	0.23	0.28	48.66
SA 1%	7.23	11.83	7.66	8.33	0.00	0.40	2.90	15.73	0.27	0.33	47.00
SA 2%	7.76	12.90	9.26	10.46	0.06	0.80	2.90	17.36	0.28	0.33	45.33
AA 1%	7.96	12.10	7.66	8.16	0.00	0.26	2.06	14.93	0.20	0.31	47.00
AA 2%	7.43	11.90	7.26	7.60	0.00	0.20	1.36	14.80	0.20	0.31	48.00
NAA 20	7.70	12.43	8.93	9.53	0.00	0.33	2.33	16.30	0.25	0.29	48.00
NAA 40	8.20	13.66	9.80	10.53	0.00	1.06	2.76	16.46	0.28	0.33	48.00
Br. 0.5	7.53	12.00	8.40	9.53	0.00	1.06	2.76	15.73	0.28	0.30	46.00
Br. 1	7.63	10.70	7.73	9.36	0.00	0.40	1.86	15.23	0.25	0.31	48.66
CW	7.16	11.03	6.96	7.43	0.00	0.46	1.46	15.80	0.23	0.31	48.66
WS	7.80	11.86	9.73	9.66	0.00	0.46	2.33	16.86	0.31	0.33	45.33
Control (Irr. 5 days)	8.80	13.06	12.60	8.80	0.40	2.86	3.86	16.63	0.31	0.28	44.33
Farmer's practice (Irr. 2 days)	9.06	13.56	15.33	12.20	0.26	3.00	4.66	19.86	0.36	0.35	44.33
Control (Irr. 5 days with imposed water stress)	7.33	10.93	7.40	7.63	0.00	0.13	2.10	11.93	0.17	0.19	48.66
CD (0.05)	NS	NS	3.01	2.09	NS	1.27	NS	2.62	0.02	0.02	NS

Table 3: Effect of plant growth regulators on chlorophyll content (35 DAS) of cowpea

Treatments	Total chlorophyll (mg/g plant)	Relative Leaf Water content (%)
CCC 10	0.13	17.17
CCC 20	0.15	27.27
SA 1%	0.14	19.57
SA 2%	0.19	29.80
AA 1%	0.15	27.37
AA 2%	0.15	22.87
NAA 20	0.16	18.50
NAA 40	0.16	23.26
Br. 0.5	0.13	22.53
Br. 1	0.13	18.43
CW	0.19	27.53
WS	0.17	26.90
Control (Irr. 5 days)	0.20	30.73
Farmer's practice (Irr. 2 days)	0.21	38.00
Control (Irr. 5 days with imposed water stress)	0.12	16.76
CD(0.05)	0.013	7.536

Table 4: Effect of plant growth regulators on yield and yield attributes of cowpea

Treatments	Pod No./plant	Pod length (cm)	Seeds/pod	Pod weight (g)	Pod yield (kg/ha)	Stover yield (kg/ha)	Total DMP* (kg/ha)
CCC 10	2.33	24.66	12.33	8.16	1537.03	2719.75	844.44
CCC 20	2.66	26.43	12.83	8.66	1629.63	3339.50	934.56
SA 1%	2.33	26.06	12.56	8.63	1866.66	3508.23	940.74
SA 2%	3.33	26.63	13.50	8.90	2962.96	3195.06	978.18
AA 1%	3.00	25.70	12.43	8.73	2151.85	2407.40	888.06
AA 2%	3.00	26.13	12.10	8.56	1740.74	2865.43	911.93
NAA 20	2.66	29.13	13.26	8.13	1951.85	3376.13	982.30
NAA 40	3.00	29.70	13.53	8.63	2774.07	4024.69	1375.72
Br. 0.5	2.66	27.20	12.83	8.73	2377.77	3531.68	1165.43
Br. 1	2.00	26.66	12.46	8.13	1040.74	2532.09	709.46
CW	2.66	26.63	12.36	8.03	1844.44	2508.64	896.29
WS	3.00	26.46	13.93	8.06	2755.55	3225.51	1109.05
Control (Irr. 5 days)	5.66	27.46	13.76	8.40	2777.77	4768.72	1422.22
Farmer's practice (Irr. 2 days)	8.00	27.76	14.00	7.93	3348.14	5097.94	1661.72
Control (Irr. 5 days with imposed water stress)	1.33	25.80	11.36	6.20	1322.22	2290.94	644.93
CD(0.05)	1.38	NS	NS	NS	498.67	415.96	184.68

*DMP- Dry matter production

Table 5: Soil moisture content during the experiment

Treatments	Soil moisture content (%)				
	15DAS	30DAS	45DAS	60DAS	At final harvest
CCC 10	9.90	6.90	9.73	8.60	6.43
CCC 20	9.23	7.10	9.83	8.47	6.57
SA 1%	9.83	7.00	9.73	8.90	6.77
SA 2%	9.23	7.33	9.23	8.17	6.37
AA 1%	9.00	6.90	9.10	8.50	6.20
AA 2%	9.20	7.23	9.00	8.77	6.77
NAA 20	9.73	7.10	9.43	8.20	6.80
NAA 40	9.20	7.23	9.73	8.87	6.80
Br. 0.5	9.47	7.30	9.83	8.87	6.13
Br. 1	9.67	7.40	9.33	8.77	6.63
CW	9.83	6.90	9.37	8.87	6.90
WS	9.90	7.33	9.73	8.77	6.77
Control (Irri. 5 days)	9.77	12.93	10.77	10.30	6.20
Farmer's practice (Irri. 2 days)	13.90	13.07	13.37	12.93	7.33
Control (Irri. 5 days with imposed water stress)	9.67	7.10	9.37	8.67	6.43
CD(0.05)	0.55	0.406	0.487	0.503	0.38

Conclusion

The present study revealed that among the stress mitigating plant growth regulators, salicylic acid @ 2%, NAA @ 40 ppm and water spray during water stress period were found beneficial for mitigating water stress in vegetable cowpea grown during summer season in laterite soils of Kerala [AEU 10:-North central laterites].

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