Iosr Journal Of Agriculture And Veterinary Science (Iosr-Javs)
E-Issn: 2319-2380, P-Issn: 2319-2372. Volume 18, Issue 4 Ser. 1 (April. 2025), Pp 06-11
www.Iosrjournals.Org

Study On The Effect Of Hydrogel On Fruit Quality And Yield Of Orange (*Citrus Reticulata*: Rutaceae) In Arunachal Pradesh, India

Oder Tabi And Dujum Kato
Orange Research And Development Centre (ORDC), Roing
State Horticulture Research & Development Institute (SHRDI)
Department Of Horticulture
Lower Dibang Valley District, Roing-792110 (Arunachal Pradesh), India

Abstract
An experiment was conducted on six year old orange (Citrus reticulata Blanco) plants to study the effect of hydrogel on the fruit quality and yield at Roing. An attempt was made to conserve the soil moisture in the root zone of the plant, received through precipitation, by the application of hydrogel at different levels ranging from 0 – 120 g of dose. The objective is to improve the fruit quality and yield of orange. Drought stress significantly limits the orange plant growth and productivity. Orange is sensitive towards water stress which directly affects the yield and fruit quality. Among the various treatments, treatment T_7 (120 g/tree) have shown the best result with a good number of fruits i.e., 178.57 fruits per tree and the fruit weight (120.12 g/fruit) and yield (21.45 kg/tree). T_7 (120 g/tree), T_6 (100 g/tree) and T_5 (80 g/tree) have shown similar result on total soluble solids (TSS), total sugar and reducing sugar. T_7 (120 g/tree) shown the highest ascorbic acid (62.64mg/100g) and leaf relative water content (97.83%). Hence it was concluded that the application of hydrogel resulted in better yield and fruit quality of orange.
Keywords: *fruit quality, hydrogel, leaf relative water content, orange, soil moisture conservation, water stress and yield*

Date of Submission: 05-04-2025 Date of Acceptance: 15-04-2025

I. Introduction

The total mandarin production in India is 62.19 lakh tons from a total area of 477000 ha with the productivity of 12.54 t/ha (Press Information Bureau, 2022). Total production of orange in Arunachal Pradesh accounts 5.95 MT/ha, which is quite low as compared to the national production of 9.23 MT/ha (Mope *et al*., 2021). This low productivity is due to negligence, malnutrition and general negligence of the citrus orchard (Chaturvedi *et al.*, 2018). Drought stress significantly limits the plant growth and crop productivity. Orange is sensitive towards water stress which directly affects the yield and fruit quality. The evergreen nature of orange plant demands a good amount of water. The juice present in the vesicles of orange fruit contains about 70-90% water, about 12% sugars, 0.5-1.5% titrable acidity and other soluble solids, 1% citric acid, about 50 mg ascorbic acid (vitamin C) per 100 ml of juice. Citric acid is the characteristic organic acid of citrus fruits. It accounts for most acidity in the fruit juice with exception like sweet lime where it is so low that malic acid exceeds citric acid (Clements, 1964). Orange in Arunachal Pradesh is grown as rainfed crop. The maximum rainfall is received during June - October months and the rest months of the year remain dry. The uneven distribution of annual rainfall has caused water stress to the plant. Moisture stress induces dormancy during November to March and failure of rain causes no flowering or less fruit bearing. Therefore the present study focuses on the improvement of fruit quality and yield of orange by soil moisture conservation using hydrogel.

Hydrogels are cross-linked polymers {polyacrylamide $(C_3H_5NO)_n$} with a hydrophilic group(Viz. acrylamide, acrylic acid, acrylate, carboxylic acid, etc.) which have the capacity to abosorb large quantities of water without dissolving in water (Schacht, 2004). The hydrophilic groups of the polymer chain are responsible for water absorption in hydrogels. Hydrogel is commonly used as a soil conditioner by the gardener and farmer. Hydrogel has various trade names and manufacturing company for instances, Pusa hydrogel (Mfg. by IARI, New Delhi), Rain drops (Mfg. by M5 exotic lifestyle concepts, Chennai), Agro-forestry water absorbent polymer (Mfg. by Technocare Products, Ahmedabad), Waterlock 95N (Mfg. by Acuro Organics Ltd., New Delhi) etc. It has the water retention capacity up to 500 times its own weight (Buchholz, 1998; Kazanskii and Dubrovskii, 1992); thereby hydrogel keeps the soil moist and hold the nutrients from leaching out and make them available to the plant in a long period of drought.Water and nutrients will remain stored into the hydrogel and released in the root zone during dryer times. Hydrogel can reduce irrigation frequencies up to 50% and remains in active for 2–3 seasons (Bore, 2023). The soil of the experiment site is sandy loam with presence of gravels and stones which caused deep percolation and less moisture retention. The present experiment was conducted to conserve the soil moisture in the root zone of the plant, received through precipitation, by the application of hydrogel at different levels ranging from 0 – 120 g of treatments, with the objective to improve the yield and fruit quality of orange through application of hydrogel.

II. Materials And Methods

The study on the effect of hydrogel on yield and fruit quality of orange (*Citrus reticulata* Blanco) was carried out during 2021 – 2022 by Orange Research and Development Centre (ORDC), Roing, Department of Horticulture, Govt. of Arunachal Pradesh. The experiment was conducted at the progressive farmers orange orchard in Roing, Lower Dibang Valley District. Six year old healthy orange plants at 6 × 6 m grown under rainfed were selected for the experiment. Randomized block design with three replication and seven treatments was laid out. After the harvest of previous year crop, the treatments were imposed during the month of December 2021. Cleaning and digging was done at the basin area of the tree. Hydrogel was applied in a circular trench measuring 30 cm wide, 15 cm deep made around the tree. 2 m radius distant from the tree trunk was maintained. Hydrogel was uniformly spread in the trench thereafter the trench was covered with pulverized soil. A general dose of fertilizer 450 g N, 450 g P_2O_5 and 900 g K_2O per plant per year was applied to all the trees. The seven treatments of hydrogel were T_1 = 0g/tree (control), T_2 = 20 g/tree, T_3 = 40 g/tree, T_4 = 60 g/tree, T_5 = 80 g/tree, T_6 = 100 g/tree, T_7 = 120 g/tree. Fully ripened fruits were harvested for the biochemical analysis of fruit quality such as TSS, total acidity, total sugar, reducing sugar, non-reducing sugar, ascorbic acid and leaf relative water content.

Yield analysis:

The data on the number of fruits per tree were recorded by counting the number of fruits on each tree at the time of harvesting. Yield (kg/tree) was estimated by multiplying the total number of fruits per tree with the average weight of the fruit (weight of 10 orange was taken randomly to determine the average weight).

Bio-chemical analysis of fruits:

For the estimation of total soluble solids(TSS), total acidity, total sugar, reducing sugar, non-reducing sugar and ascorbic acid content, the fruit juice was extracted after peeling and squeezing out the juice through a muslin cloth. The fresh juice was used for the bio-chemical analysis.

Total soluble solids (TSS)

The TSS (Total Soluble Solids) content of fruit was recorded with the help of a hand refractometer caliberated in 0°Brix at 20˚C.

Total acidity (%)

Titratable acidity of the extracted juice was determined by titrating it against N/10 NaOH solution using phenolphthalein as an indicator and results were expressed as percentage citric acid (AOAC, 2002).

Total sugar (%)

The estimation of total sugar of fruit juice was determined by Anthrone method given by Hodge and Hofreiter (1962). In this method a known sample weight of the fruit was taken and hydrolyzed by dilute hydrochloric acid by keeping it in a boiling water bath for three hours. It was cooled, neutralized and centrifuged. The supernatant formed was then mixed with Anthrone reagent (as indicator) to give a green colour product with a maximum absorption at 630nm.

Amount of carbohydrate present in 100 mg of the sample =

$$\frac{\text{mg of glucose}}{\text{Volume of test sample}} \times 100$$

Reducing sugar (%)

The Reducing sugar content was estimated by spectrophotometric method as described by Somogyi (1952). One gram of the ripe fruit was weighed and macerated with 5ml of hot 80% ethanol and supernatant was collected. Then it was evaporated in water extract in different volume, the absorbance was recorded at 620 nm in spectrophotometer and compared against standard.

Non-reducing sugar %

Non-reducing sugar was estimated by traditional method as described by Kumar (2002). It was estimated by subtracting reducing sugar from total carbohydrate and then multiplying it with 0.95.

Ascorbic acid (vitamin c)

The ascorbic acid content was determined according to the method described by Jagota and Dani (1982). 2 ml of the sample juice was mixed with equal volume (2 ml) of 6% metaphosphoric acid EDTA (0.18 g) solution and the volume made up to 10ml with 3% metaphosphoric acid and kept for around 15 minutes. The above mixture was centrifuged at 5000rpm for 10 minutes and then filtered through Whatman no.1 filter paper and collected in volumetric flask. An aliquot of the sample extract (0.1 ml) diluted to 1.2 ml with 3% metaphosphoric acid and made up the volume upto 4 ml with distilled water. To each tube 0.4 ml Ciocalteau reagent was added and mixed well. The tubes were incubated for 10 minutes at room temperature and centrifuged at 3000 rpm for 10 minutes. After centrifugation, supernatant solution was read against the blank solution in a spectrophotometer at 760nm. The concentration of ascorbic acid in the sample was calculated from the slope of the ascorbic acid of the acid standard curve. The result was expressed as 'mg' of ascorbic acid/100g of the sample.

$$\text{Vitamin C (mg/100g)} = \frac{\text{Total volume of the sample X Conc.of Vit.C X 100 X 1}}{\text{Weight of sample X Amount of sample X 1000}}$$

Leaf relative water content %

Plant leaves generally have lower (more negative) water potential than pure water; hence they osmotically absorb water and become turgid. A measure of this property is the relative water content (RWC) which expresses the leaf water content (%) of the turgid leaf water content.

Relative water content (RWC) is the appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit. While water potential as an estimate of plant water status is useful in dealing with water transport in the soil-plant-atmosphere continuum, it doesn't account for osmotic adjustment (OA). OA is a powerful mechanism of conserving cellular hydration under drought stress and RWC expresses the effect of OA in this respect. Hence RWC is an appropriate estimate of plant water status in terms of cellular hydration under the possible effect of both leaf water potential and OA.

The relative water content was estimated based on the method of Barrs and Weatherley (1962). The leaf discs were taken from 3rd leaf from the top of the plant and weighed to indicate fresh weight. Immediately after weighing, the leaf discs were transferred to Petri dishes containing water. After 4 hours, leaf material was surface blotted and weighed once again to indicate turgid weight. The leaf discs were then oven dried at 80ºC up to 48 hours and their dry weights recorded. By using all these parameters RWC (%) was calculated as shown below.

$$\text{RWC (\%)} = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

The data obtained was analyzed by using the analysis of variance for randomized block design as described by Panse and Sukhatme, (1985). The level of significance used in F-test was 0.05 and critical difference (CD) values were calculated whenever the F-test was significant. The data was analysed statistically by using the MS excel and WASP 1.0.

III. Results And Discussion

Yield parameter

Data recorded on yield with respect to number of fruits per tree (kg), yield per tree and yield per hectare (tons) showed significant variation among the different treatments. Table 1 shows the maximum number of fruit per tree was observed in treatment T_6 (180.67) followed by T_7 (178.57) and T_5 (169.00). However, statistically T_6 was at par with T_7 and T_5, while the minimum number of fruits per tree was recorded in control T_1 (105.04).

In the same manner, treatments had shown significant effects on yield per tree (kg) and yield per hectare (tons) as presented in Table 1. The highest yield, in term of kilogram per tree and tons per hectare, was recorded in treatment T_7 (21.45 kg/tree & 5.94 t/ha) followed by T_6 (21.38 kg/tree & 5.92 t/ha), T_5 (19.84 kg/tree & 5.49 t/ha), T_4 (17.33 kg/tree & 4.80 t/ha), T_3 (14.29 kg/tree & 3.90 t/ha) and T_2 (12.76 kg/tree & 3.53 t/ha) while the lowest yield was recorded in control T_1 (11.48 kg/tree & 3.17 t/ha).

Yield is a complex character which involves the interaction of several intrinsic and external factors. It largely depends upon the production and mobilization of carbohydrates, uptake of water and nutrients from the soil, in addition to several environmental factors to which plant is exposed during the growing period (Schaffer and Anderson, 1994).

The present study indicated that the yield determining components such as number of fruits, fruit weight and fruit size were found to be significantly higher with an increase in the concentration of hydrogel. Similar results have been reported by Sivalapan (2001) with the soil incorporation hydrophilic polymer in soybean, Sendur et al. (2001) in tomato and El-Hady and Wanas (2006) in cucumber under water stress conditions.

The above results were finds support from the results obtained by Pattanaaik *et al.,* (2015) who reported that the application of hydrogel (60g/tree) on 7– 8 years old Khasi mandarin, the yield and the number of fruits per tree (283) increase with largest fruit size as well. In the same manner, Szwonek (2012) reported in sweet cherry trees, resulting in a yield increase from 3.2 to 11.6 kg/tree. Similarly, results have been reported in field crops by Langaroodi *et al.,* (2013) in peanut; Singh (1998) in potato and onion; Tripathi *et al.,* (1997) in Indian mustard cv. Varuna; and Volkamar and Chang (1995) in barley.

Fruit quality and biochemical parameters

In the present study the maximum TSS (10.73°Brix) was recorded in T_5 (80g per tree) and at the same time, T_5 was at par with T_6 (100g per tree) and T_7 (120g per tree). However, the minimum TSS (9.70°Brix) was recorded in T_1 (control). Similar effect on TSS due to different moisture level in the soil has been observed by Singh *et al.,* (2014) in mango cv. Amrapali; Sendur *et al.,* (2006) in tomato var. Co-3; and Zhu *et al.,* (2002) in sugarcane.

Total acidity was found to be decreasing with an increase in concentration of hydrogel. The control resulted in highest (0.254%) total acidity, while the lowest value (0.219%) was observed in T_7 (120g per tree). This finding is supported by Singh *et al.,* (2014) in mango cv. Amrapali.

Total sugar of the fruit was found maximum in treatment T_7 (120g per tree) i.e., 9.71%. Statistically, T_7 was found to be at par with T_6 and T_5. However, the minimum value 7.33% was recorded in control T_1. Similarly, reducing sugar of the fruit was also found to be highest in treatment T_7 (120g per tree) i.e., 4.02% while lowest value was 2.70% in T_1 (control). However, statistically T_7 was found at par with T_6 and T_5. In case of Non-reducing sugar treatments were found to be significantly varying. Statistically, T_6 was recorded highest i.e., 5.41% while lowest record was 4.40% in control T_1. The treatment T_6 was found to be at par with T_7, T_5, T_4 and T_3.

In case of ascorbic acid content, significant variation was observed. T_7 (120g per tree) recorded highest (62.64mg/100g) while lowest in T_2 (20g per tree) i.e., 57.75mg/100g. Statistically, T_7 is at par with T_5. For leaf relative water content, treatments T_7 (120g per tree) was recorded maximum i.e., 97.83% while minimum was found in T_1 i.e., 94.04%. Above mentioned results finds support from Sendur *et al.,* (2006) who reported an increase in ascorbic acid content, TSS, pH, lycopene content and juice content in tomato var. Co-3 due to the application of hydrophilic polymer. Similarly, Wallace and Wallace (1986) reported on nutritional quality of tomato. Even, Volkamar and Chang (1995) reported the influence of hydrophilic polymer (Grogel) on leaf relative water content in barley. In the same manner, Zhu *et al.,* (2002) observed increase in sucrose content, gravity purity and Brix after the imposition of superabsorbent polymer in sugarcane.

Water has been rightly designated as "blood of life" because of its central role in living systems responsible for many biochemical reactions and translocation of nutrients in liquid form which is essential for life. Ahmed *et al.,* (1989) reported that water stress has a pronounced alternation in the metabolism of nitrogenous compounds. For instance, Nitrate reductase activity (NRA) has been shown to be regulated by various factors such as its substrates (NO_3), nitrogen metabolites, light, temperature, carbon dioxide, moisture, oxygen etc. (Abdin *et al.,* 1993). In the present study, it is observed that hydrogel has a profound influence on leaf relative water content (RWC) which might suit best for metabolism of nitrogenous compounds. A significant increase in leaf relative water content (RWC) was observed with an increase in concentration of hydrogel in the soil.

Application of hydrogel into the soil exhibited significant differences in nitrate reductase activity in leaf. The enzyme nitrate reductase catalyses the reduction of nitrate to nitrite and is the rate limiting step in nitrogen metabolism which takes place in the cytoplasm of the cell in both roots and shoots (Kumar *et al.,* 1989). It has been reported by Bowerman and Goodman (1971) that the leaf dry matter accumulation is significantly and positively associated with corresponding nitrate reductase activity (NRA) in collium. It has been observed that the NRA increased with an increase in the concentration of hydrophilic polymer (HP) in the soil at all the stages, except at harvest. NRA was more at 60 DAT and decreased later on and it is generally believed that NRA depends on the activity of substrate and proteinaceious compounds and therefore it is reported that the application of hydrophilic polymer (hydrogel) results in the enhanced nitrate uptake by the plants (El-Sayed *et al*., 1995).

Table 1: Effect of hydrogel on number of fruits per tree and yield.

Treatment: Hydrogel Used	No. of Fruits per tree	Mean fruit weight (g)	Yield per tree (kg)	Yield per hectare (t/ha)
T1: 0 g/tree	105.04	109.22	11.48	3.17
T2: 20 g/tree	113.77	112.13	12.76	3.53
T3: 40 g/tree	124.74	114.52	14.29	3.96
T4: 60 g/tree	149.67	115.85	17.33	4.80
T5: 80 g/tree	169.00	117.43	19.84	5.49
T6: 100 g/tree	180.67	118.44	21.38	5.92
T7: 120 g/tree	178.57	120.12	21.45	5.94
CV	5.793	1.239	5.517	5.520
CD at 5%	15.040	2.544	1.662	0.461

Table 2: Effect of hydrogel on biochemical parameters of orange.

Treatment: Hydrogel used	TSS(ºBrix	Total acidity(%)	Total sugar (%)	Reducing sugar(%)	Non-reducing sugar(%)	Ascorbic acid (mg/100g)	Leaf relative water content(%)
T1: 0 g/tree	9.70	0.254	7.33	2.70	4.40	57.80	94.04
T2: 20 g/tree	9.87	0.246	8.26	3.14	4.87	57.75	94.50
T3: 40 g/tree	10.23	0.246	9.06	3.60	5.19	58.20	95.45
T4: 60 g/tree	10.37	0.226	9.27	3.77	5.23	59.54	96.35
T5: 80 g/tree	10.73	0.228	9.53	3.89	5.31	62.31	96.39
T6: 100 g/tree	10.73	0.220	9.70	4.01	5.41	61.25	97.09
T7: 120 g/tree	10.63	0.219	9.71	4.02	5.37	62.64	97.83
CV	0.772	1.563	1.568	2.329	2.389	0.532	0.304
CD at 5%	0.142	0.007	0.250	0.149	0.217	0.567	0.518

IV. Conclusion

Since irrigation water is a limiting factor in India particularly Arunachal Pradesh; it is important to improve the water use efficiency of the plants. The use of water retaining polymers viz., hydrogel has potential for horticultural and other crops. The results of this study have shown that the crop yield could be improved by adding hydrogel to the soil as the polymer in soil can absorb and store extra water in the soil and enable the plants to utilize that water over an extended period of time. Application of hydrogel should be popularised in areas lacking assured irrigation facilities and in areas with undulating topography where layout of irrigation facilities is difficult with an objective to conserve soil moisture received through precipitation. Hydrogel will prove to be an important component in the integrated approach for conservation of soil moisture and enhance the yield and fruit quality of orange.

Acknowledgement

The authors are obliged to Shri. Egam Basar the Head of SHRDI, Itanagar and Prof. Barun Singh, Department of Fruit Science, College of Horticulture & Forestry, CAU, Pasighat, Arunachal Pradesh for their guidance and inputs.

References

[1] Abdin, M.Z., Lakkineni, K.C. And Kumar, P.A. 1993. Molecular Aspects Of Nitrate Reductase Regulation In Higher Plants. In: Nitrogen- Soils, Physiology, Biochemistery, Microbiology, And Genetics.(Eds. Abrol. Y.P. Tilak, K.V.B.R., Kumar, S. And Katyal, J.C.). Indian National Science Academy, New Delhi. Pp. 59-66.

[2] Ahmed, A.M., Radi, A.P., Shaddad, M.A. And El-Aayeb, M.A. 1989. Effect Of Phytohormones On Carbohydrates And Nitrogen Metabolism Of Some Drought Stressed Crop Plants. Journal Of Islamic Academy Of Sciences, 2: 93-99.

[3] Al-Harbi, A.R., Al-Omran, A.M., Choudhary, M.I., Wahdan, H. And Mursi, M. 1996. Influence Of Soil Conditioner On Seed Germination And Growth Of Cucumber. Arab Gulf Journal Of Scientific Research, 14(1): 129-142.

[4] A.O.A.C. 2002. In: Official Methods Of Analysis, Association Of Official Analytical Chemists International, Washington. DC.

[5] Azavedo, T.L., Bertonha, A. And Rezende, R. 2002. Levels Of Hydrophilic Polymer, Irrigation Interval And Coffee Plant Growth. Acta Scientiarum, 24(5): 1239-1243.

[6] Barrs, H.D. And Weatherley, P.E. 1962. A Re-Examination Of The Relative Turbidity Technique For Estimating Water Deficit In Leaves. Australian Journal Of Biological Sciences, 15: 413-428.

[7] Borre, P.V.D.,2023. Stockosorb 660-Water & Soil Management. Available At Https://Www.Eco-Plus.Ca/Blog/Post.Php?S=2020-05-19-Stockosorb-660-Water-Soil-Management(19th May 2020).

[8] Bowerman, A. And Goodman, G. 1971. Variation In Nitrate Reductase Activity In Collium. Annals Of Botany, 35: 353-366

[9] Buchholz, F.L., 1998. The Structure And Properties Of Superabsorbent Polyacrylates. In Buchholz, F.L., Graham, A.T., (Eds.), Modern Superabsorbent Polymer Technology. Wiley-VCH, New York, Pp. 167–221.
[10] Chaturvedi, A., Pandey, N.K., Indu, Tripathi, P.P., Mishra, R.C., Tripathi, A.N., 2018. Rejuvenation Of Citrus In Arunachal Pradesh. International Journal Of Pure And Applied Biosiences. 6(4), 688–695.
[11] Clements, R.L. 1964. In: A Text Book On Pomology Subtropical Fruits, Volume-III, (Ed. Chattopadhayay, T.K.). Kalyani Publishers, Rajinder Nagar, Ludhiana, India, Pp. 2.
[12] El-Hady, O.A. And Wanas, S.A. 2006. Water And Fertilizer Use Efficiency By Cucumber Grown Under Stress On Sandy Soil Treated With Acryamide Hydrogels. Journal Of Applied Sci. Res., 2(12): 1293-1297.
[13] El-Sayed, F.M.A. And Abdul-Rahik, M. 1995. In: A Text Book Of Pomology Subtropical Fruits, Volume-III. (Ed. Chattopadhayay, T.K.). Kalyani Publishers, Rajinder Nagar, Ludhiana, India, Pp.2.
[14] Hodge, J.E. And Hofreiter, B.T. 1962. In: Carbohydrate Chemistry, 17 (Eds. Whistler, R.L. And B Miller, J.N.). Academics Press, New York.
[15] Jagota, S.K. And Dani, H.M. 1982. A New Colorimetric Technique For Estimation Of Vitamin C Using Folin-Phenol Reagent. Analytical Biochemistry, 127(1): 178-182.
[16] Kazanskii, K.S., Dubrovskii, S.A., 1992. Chemistry And Physics Of Agricultural Hydrogels. Advances In Polymer Sciences. 104, 97–133.
[17] Kumar, S. 2002. Studies On The Effect Of VAM & Growth Regulators On Gladiolus Grandiflorus L. Cv. Jessica. Ph.D Thesis Submitted To CCS Haryana Agricultural University, Hissar Haryana.
[18] Kumar, P.A., Nair, T.V.R. And Abrol, Y.F. 1989. Nitrate Reductase: Localization And Source Of Reductant. In: Proceedings Of Indian National Science Academy, 54:409-412.
[19] Langaroodi, N.B.S., Ashouri, M., Dorodian, H.R. And Azarpour, E. 2013. Study Effects Of Super Absorbent Application, Saline Water And Irrigation Management On Yield And Yield Components Of Peanut (Arachis Hypogaea L.). Annals Of Biological Research, 4(1): 160-169.
[20] Mope, H., Langdo, T., Leriak, J., 2021. Statistical Abstract Of Arunachal Pradesh-2021. Directorate Of Economics & Statistics, Government Of Arunachal Pradesh, Pp. 36.
[21] Panse, V.G. And Sukhatme, P.V. 1985. Statistical Methods Of Agricultural Workshop. ICAR, New Delhi.
[22] Pattanaaik, S.K., Wangchu, L., Singh, B., Hazarika, B.N., Singh, S.M., And Pandey, A.K. 2015. Effect Of Hydrogel On Water And Nutrient Management Of Citrus Reticulate. Research On Crops, 16(1): 98-103.
[23] Press Information Bureau, 2022. Second Advance Estimates Of Area And Production Of Horticultue Crops, In: Horticultural Crops 2021–2022. Available: Https://Static.Pib.Gov.In/Writereaddata/Specificdocs/Documents/ 2022/Jul/Doc202271470601.Pdf (Posted On: 14th July 2022).
[24] Sanliang, G., Fuchigami, L.H. And Guak S.H. 1996. Effects Of Short-Term Water Stress, Hydrophilic Polymer Amendment And Antitranspirant On Stomatal Status, Transpiration And Growth In 'Better Boy' Tomato. Journal Of American Horticultural Sci., 121(5): 831-837.
[25] Schacht, E. H., 2004. Polymer Chemistry And Hydrogel Systems. J. Phys.: Conf. Ser. 3: 22-28.
[26] Schaffer, B. And Anderson, P.C. 1994. Subtropical And Tropical Crops. In: Handbook Of Environmental Physiology Of Fruit Crops (Eds. Schaffer, B. And Anderson, P.C.). CRC Press, USA, Pp. 465-190.
[27] Sendur, K.S., Natrajan, S., Muthvel, I. And Sathiayamurthy, V.A. 2001. Standardization Of Hydrophilic Polymers On Growth And Yield Of Tomato. Journal Of Madras Agric., 88(1-3): 103-105.
[28] Sendur, K.S., Natrajan, S., Muthvel, I. And Sathiayamurthy, V.A. 2006. Efficacy Of Graded Doses Of Polymers On Processing Quality Of Tomato Cv. CO3. Madras Agricultural Journal, 88(4-6): 298-299.
[29] Singh, J. 1998. Effect Of Stockosorb Polymers And Potassium Levels On Potato And Onion. Journal Of Potassium Res. 14: 78-82.
[30] Singh, S.R., Banik, B.C. And Hasan, M.A. 2014. Effect Of Water Regulation In Bearing Period For Yield And Quality In Mango Cv. Amrapali. Research On Crops 15(4): 833-838.
[31] Sivalapan, S. 2001. Effect Of Polymer On Growth And Yield Of Soybean (Glycine Max L.) Grown In A Coarse Textured Soil, In: Proceeding Irrigation, 2001 Regional Conference, Toowoomba, Queensland, Australia, Pp. 93-99.
[32] Somogyi, N. 1952. Journal Of Biological Chemistry, 200:245
[33] Svenson, S. S. 1993. Growth Responses Of West Indies Mahogany To Contiuemtm Or Osmocotetm Application During Transplanting. Tropicline, 6(1): 144-147.
[34] Szwonek, E. 2012. Impact Of Superabsorbent Gel And Organic-Mineral Fertilizer On Growth, Yield And Quality Of Sweet Cheery Trees. Acta Horticulturae, 940: 415-421.
[35] Tripathi, M.L., Kurmavanshi, S.M. And Namdeo, K.N. 1997. Effect Of Starch Polymer And N- Triacontanol On Growth And Yield Of Indian Mustard Cv. Varuna. Indian Journal Of Agron., 42(1): 194-195.
[36] Volkamar, K.M. And Chang, C. 1995. Influence Of Hydrophilic Gel Polymers On Water Relations, Growth And Yield Of Barley And Canola. Can. J. Plant Sci., 75: 605-611.
[37] Wallace, A And Wallace, G.A. 1986. Effects Of Soil Conditioners On Emergence And Growth Of Tomato, Cotton And Lettuce Seedlings. Soil Science, 141(5): 313-316.
[38] Zhang-Zhang Jiang, Shi-Lei Zhang-Chengyi And Zhang Jin Zheng. 2005. Response Of Hydrophilic Polymer Under Different Water Gradients On Growth Characteristics Of Parthenocissus, Quinquefolis. Bulletin Botanical Research, 25(1): 74-79.
[39] Zhu Luo-Ming., Liu-Zinan., Liang-Jinan. And Luo-Chao Liang. 2002. Effect Of Water Holding Agent On Yield And Quality Of Sugarcane. Sugarcane, 10(3): 13-16.