IMPACT OF FOLIAR SPRAY OF POTASSIUM, BORON AND BRASSINOLIDE IN IMPROVING ASSIMILATE PARTITIONING IN TROPICAL SUGAR BEET

Thesis submitted in part fulfillment of the requirement for the degree of MASTER OF SCIENCE (AGRICULTURE) in CROP PHYSIOLOGY to the TAMIL NADU AGRICULTURAL UNIVERSITY Coimbatore - 641 003

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CERTIFICATE

This is to certify that the thesis entitled **"IMPACT OF FOLIAR SPRAY OF POTASSIUM, BORON AND BRASSINOLIDE IN IMPROVING ASSIMILATE PARTITIONING IN TROPICAL SUGAR BEET"** submitted in part fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) IN CROP PHYSIOLOGY** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Mr. M. KARTHIK** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles, prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

Place: Coimbatore **(Dr. K. SUBBURAMU)**
Date : Chairman

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Date: External Examiner:

ABSTRACT

IMPACT OF FOLIAR SPRAY OF POTASSIUM, BORON AND BRASSINOLIDE IN IMPROVING ASSIMILATE PARTITIONING IN TROPICAL SUGAR BEET

By

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Studies were conducted to understand the impact of foliar feeding of potassium and boron nutrients and brassinolide, a plant growth regulator to improve the growth, development, yield and quality of tropical sugar beet CV. Indus. The treatments include foliar spray of potassium chloride 1 %, boric acid 0.5 % and brassinolide 0.5 ppm either individually or in combination given as a single spray at 50 DAS or as double spray at 50 and 75 DAS.

The plant height, leaf number, leaf area and LAI of sugar beet increased with time trend and reached a static growth at 120 DAS and declined at harvest due to senescence of lower leaves. The plant vigour in terms of leaf number, leaf area and plant height was significantly increased by foliar spray of nutrients and plant growth regulator and is positively related to yield.

The combination spray of KCl 1 % + boric acid 0.5 % + brassinolide 0.5 ppm given twice on 50 and 75 DAS was identified as the most effective treatment which was followed by the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS. The supplementary sprays of nutrients and plant growth regulator had beneficial effect through the delayed leaf senescence. The most effective treatment had its positive influence on other growth parameters *viz.* SLW, RGR, NAR CGR, and total dry matter production. All these growth parameters were positively related to yield.

The combination spray of KCl 1 % + boric acid 0.5 % + brassinolide 0.5 ppm given twice on 50 and 75 DAS also enhanced photosynthetic pigments, soluble protein content and sucrose synthase activity in leaves results in increased levels of TSS and sugars in tubers.

The supplementary nutrients and plant growth regulator sprays were also effective in improving tuber characteristics. Combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was found to be more effective in improving HI and sugar beet yield followed by the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS.

High net income of Rs. 18,019 ha^{-1} with a benefit: cost ratio of 1.50 was achieved by the combination spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS. Although, combination sprays of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS recorded higher yield, net income and benefit cost ratio was low due to high cost of brassinolide included in the combination spray.

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CHAPTER I

INTRODUCTION

Sucrose is synthesized in most plants as a temporary storage product for photosynthetically reduced carbon, and is the most common form of carbon translocated in plants. Most plants convert photosynthates to starch for long-term storage. However, sucrose accumulates to an exceptional degree in two species, sugar beets (*Beta vulgaris* L.) and sugarcane (*Saccharum officianarum* L.), which together form the basis for greater than 90 % of the world's sugar trade. The sucrose derived from these two species represents approximately 11 % of the world's food supply, and 0.2 % of all the carbon fixed via photosynthesis by the world's crops each year. The estimate for world sugar production is 114.3 million tons, of which one third is derived from sugar beets, and two thirds from sugar cane (Stephen Koffka *et al*., 1992).

Sugar beet (*Beta vulgaris var. saccharifera L*.) is a biennial sugar producing tuber crop, grown basically in temperate countries. Now tropical sugar beet varieties are gaining momentum in tropical and sup tropical countries including Tamil Nadu as a promising alternative energy crop for the production of sucrose and ethanol. The ethanol can be blended with petrol or diesel up to 10 % and used as a bio-fuel. Sugar beet has now emerged as commercial field crop because of the favourable characters like (1) Short duration of 5 to 6 months (2) Moderate water requirement of 80 -100 cm (3) Higher sugar content of 12 to 15 % (4) Improvement of soil conditions because of tuber crop and (5) Suitability for saline and alkali soils. Sugar beet can supplement the sugarcane by producing beet sugar and ethanol. At present, only 1.2 billion liters of ethanol is being produced from sugar mills and there is a hope in India to produce a minimum of 4 to 5 billion liters of ethanol from sugar beet with a saving of Rs. 100 billion of foreign exchange per year, if we create awareness on the use of ethanol blended petrol in future (Syngenta, 2005).

Comparative analysis of sugar beet and sugarcane crop

Character	**Sugar beet**	**Sugarcane**
1. Duration	5 - 6 months	10 -12 months
2. Brix reading	23 - 24 %	18 - 20 %
3. Pol %	20 - 22	13 - 16
4. Sugar recovery	15 - 16 %	11 - 12 %
5. Factory average	10 - 12 %	8 - 10 %
6. Yield	100 t ha^{-1}	100 t ha^{-1}
7. Water requirement	600 - 800 mm	2000 mm

The sugar beet crop is cultivated successfully in a wide range of climates on many different soils. Not only is sugar beet grown under a wide range of climates but the soils where the crop is cultivated also vary greatly. Soils which are cultivated and cropped continuously have many features in common, particularly in relation to their supply of the major nutrients required by sugar beet (Draycott, 1966). Like other root crops, sugar beet responds well to fertilizers. It requires continuous and adequate supply of N, P, K and micronutrients particularly boron. Nutrition of sugar beet varies from place to place depending on soil type, soil nutrient status, cultivar, irrigation facility etc. Apart from yield, nutrition affect the root shape, size, colour, soluble solids, total sugars, juice quality and other physico-chemical qualities of roots (Kabir, 1990).

Boron and potassium plays an important role in improving photo assimilate production and partitioning infavour of tuber development and sucrose accumulation in crop plants. Sugar beet is classified as a potassium and boron loving crop (Russell *et al.*, 1969). If the availability of potassium and boron is low in sugar beet crop, it will affect the photo assimilates translocation to the storage root. The supplementation of potassium and boron through soil and foliar applications at critical yield deciding phases will improve the metabolic activities resulting desirable yield improvement.

Potassium involved in carbohydrate metabolism, and also more than 40 enzymes that either do not function at all or function at a reduced rate in the absence of potassium. From the foregoing it becomes evident that K^+ is very intimately associated with substances that are responsible for plant metabolic process. This is despite the fact that K ions exist in plants essentially in solution as ionic form (Mita *et al.*, 1990). Potassium deficiency causes the necrosis in sugar beet leaves (Ulrich and Hills, 1969), changes in carbohydrate metabolism and reduced in photosynthetic rate (Evans and Sorger, 1966).

Among the micro nutrients, boron is essential for sugar beet production. Since boron plays a key role in the development, cell elongation and structural integrity of plant cell walls (Skok, 1957) and translocation of sugars (Berger, 1949). Boron appears to be phloem mobile in all species in which sorbitol and mannitol, boron binding polyols is a primary translocated photosynthate (Brown and Hu, 1996). Boron enhances the up take and transport of sugars in plants and play a vital role in sugar translocation in sugar beet (Russell *et al.*, 1969). Boron deficient plants may be stunted, it affects the root growth in sugar beet (Russell *et al.*, 1969), also affects sugar transport in plants (Ecochem, 1993).

Under drought condition use of boron containing fertilizer in sugar beet increases sugar yield (Szava and Szabo, 1994).

The recognition that certain pollen extracts causes growth promotion paved the way for the discovery of brassinosteroids in plants. Steroids play a role as essential hormones in plants as well as in animals. Plants produce numerous steroids and sterols, some of which are recognized as hormones in animals (Geuns, 1978). Brassinolide (Br) is the most bioactive form of the growth-promoting plant steroids termed brassinosteroids (Grove *et al.,* 1979). The physiological functions of brassinosteroids are plant hormones with significant growth – promoting activity. Brassinosteroids increased the root growth and root biomass in sugar beet (Schilling *et al.,* 1991).

Since, Sugar beet is a new crop to tropical condition; it is pertinent to the plant physiologist to bestow their attention on this crop for improving the productivity through physiological manipulations. The present study was conducted to enhance CO_2 assimilation and partitioning with the following objectives to have an insight on sugar beet production.

1. To study the effect of potassium, boron and Brassinolide in enhancing CO_2 assimilation and assimilate partitioning in sugar beet
2. Improving the yield and quality of sugar beet by improving assimilates partitioning through transport facilitators and CO_2 assimilation activators

CHAPTER II

REIVEW OF LITERARURE

Sugar beet (*Beta vulgaris* L.), a member of the *Chenopodiaceae* subfamily and the *Amaranthaceae* family, is a plant whose root contains a high concentration of sucrose. It is grown commercially for sugar. Sugar beet is a hardy biennial plant that can be grown commercially in a wide range of temperate climates. During its first growing season, it produces a large storage root (1 - 2 kg) whose dry mass is 15 - 20 % sucrose by weight. If not harvested, during its second growing season, the nutrients in this root are consumed to produce the plant's flowers and seeds. In commercial beet production, the root is harvested after the first growing season, when the root is at its maximum size. Attempts have been made to increase the yield and quality of sugar beet through foliar feeding of nutrients and growth regulators. Of this the effect of nutrients and growth regulators especially supplementary nutrition of potassium, boron and brassinolide, recently recognized plant growth regulator in improving yield in commercial sugar beet cultivation has received much attention and favourable responses have been obtained in this crop, elsewhere. The brief review on the effect of potassium, boron and brassinolide on sugar beet and related crops is presented here.

Like other root crops sugar beet responds well to fertilizers. It requires continuous and adequate supply of nitrogen, phosphorus, potassium and micronutrients particularly boron. Nutrition of sugar beet varies from place to place depending on soil type, soil nutrient status, cultivars, irrigation facility etc. Apart from yield, nutrition affects the root shape, size, colour, soluble solids, amino acids, total sugars, juice quality and other physico-chemical qualities of roots (Kabir, 1990). Boron and potassium play an important role in improving photo assimilate production, partitioning infavour of tuber development and sucrose accumulation in sugar beet. Potassium is one of the three macronutrient plays a pivotal role in plant growth and other developmental process of sugar beet (Cooper *et al.,* 1967; Geiger and Conto, 1983). Potassium increases the photosynthetic efficiency through induction of the CO_2 assimilation activators, and also enhances the efficiency of enzyme involved in CHO and nucleic acid metabolism (Jones, 1966). Among the micronutrients, boron is essential for sugar beet production. Since boron plays a key role in the development, cell elongation and structural integrity of plant cell walls (Skok, 1957). Boron plays an important role in the translocation of sugars (Berger, 1949).

The present study also focused the role of brassinosteroids (Br) on growth and development of sugar beet. The recognition that certain pollen extracts causes growth promotion paved the way for the discovery of brassinosteroids in plants. The physiological functions of brassinosteroids are plant hormones with significant growth – promoting activity. Brassinosteroids also confer resistance to plants against various abiotic stresses (Seeta Ram Rao, 2002). Foliar application of Br increased root biomass of sugar beet (Schilling *et al.,* 1991).

Several reports have suggested that the vegetative growth of sugar beet has been largely influenced by adequate supply of nitrogen; there by increasing the source strength, this increased source strength has to be harnessed by effectively partitioning the assimilate from source leaves to the developing tubers by curtailing excess vegetative growth through the employment of suitable nutrients and plant growth regulators.

2.1. Morphological traits

Plant height is one of the growth parameters which are quite often influenced by the applied nutrients. As the level of K increased, the height of plant also increased (Nair, 1982). Potassium application increased the plant height in many crops viz. alfalfa (Kimbrough *et al.,* 1971), soybean (Hall mark and Barber, 1981), cassava (Suyamto, 1998: Nair and Aiyer, 1985), and *Mentha arvensis* L. (Srivastava and Luthra, 1992).

Boron is essential for normal growth and production of sound, healthy vegetables and it has been linked with initiation and development of growing points. A shortage of B is most often noted by a change in plant structure in these actively growing regions (Reeve *et al.,* 1944). The soil and foliar application of boron increased the growth of tomato plants (Das and Patro, 1989; Singh and Verma, 1991), where as its deficiency depressed the plant growth and development in cotton crops (Qosterhuis and Zhao, 2002). It also significantly reduced both shoot and root growth in tomato and okra seedlings (Desiraju *et al*., 1993).

Brassinolide promotes elongation of soybean, mung bean, and pea epicotyls, and also elongation of bean, sunflower and cucumber hypocotyls and wheat coleoptiles (Seeta Ram Rao, 2002).

2.2. Growth analysis

In general, high yielding varieties of crops recorded 10 % more leaf area than the low yielders (Wallace *et al*., 1972). Leaf area index (LAI) is an important determinant of dry matter production and yield. Higher LAI could usually be achieved by increasing plant population density and nutritional supply, especially potassium (Anon. 1976). Leaf area duration (LAD) is an important factor for growth and development of a crop (Evans *et al.,* 1975). Specific leaf weight (SLW), which is leaf dry weight / leaf area, is an indicator of high net photosynthetic rate (Barnes *et al.,* 1969) and dry matter production (Veerawudh, 1974).

Significant effect of K on leaf initiation in soybean was shown by Huber (1985). The K deficiency reduces the leaf area and rate of formation of green plant material (Quing-Yuan, 1983). Sugar beet well supplied with potassium produced large leaf area and more amount sugars, where as lack of potassium leads to severe wilting symptoms in leaves (Sarkar *et al.,* 1987; Li Yu-ying and Liang Hong 1997). In Taro (*Colocasia esculenta*), successive increments of K showed a significant impact of plant height and leaf area (Nair, 1982; Sarkar *et al.,* 1987). In alfalfa, foliar feeding of K increased the leaf growth and leaf area (Kimbrough, 1971).

The growth rates, net assimilation rate (NAR), relative growth rate (RGR) and crop growth rate (CGR) directly or indirectly affect the yield in view of their direct or indirect interrelationship between themselves. Potassium fertilization in sweet potato increased growth parameters like dry matter production, LAI, LAD, CGR, NAR and RGR (Chakrabarty *et al.,* 1983) and also in sun flower (Vaeinberg, 1990). The response of potassium fertilization was more pronounced when it was applied in splits in sweet potato (Mukhopadhyay *et al.,* 1992). Foliar feeding of K in higher level also increased LAD in sweet potato

(Hann, 1977); CGR was increased exponentially till the 60th day along with LAI reaching a peak on the 120th day after planting (Agata, 1982).

Application of borax in sugar beet through foliar feeding significantly increases the total dry matter production (Hassanin and Abuldahab, 1991). The beneficial effect of B was well documented in other field crops viz. sun flower (Ateeque *et al.,* 1993), cauliflower cv. (Thakur *et al*., 1991; Gyul'akhmedov and Gasanova, 1990), soybean cultivars (Yamagishi and Yamamoto, 1994).

The physiological functions of brassinosteroids are plant hormones with significant growth – promoting activity. Brassinosteroids also confer resistance to plants against various abiotic stresses (Seeta Ram Rao, 2002). Physiological responses of brassinolides include effects on elongation, cell division and vascular development (Mitchell and Gregory, 1972: Yokota *et al*., 1982 and 1985; Katsumi, 1985; Fujioka and Sakurai, 1997). Brassinolides treatments increased the leaf area development appeared to aid in the light interception and drymatter production in soybean (Wallace *et al*., 1972), strawberry (Krizek and Mandava, 1983; Pippatanawong *et al.,* 1996), tobacco (Diz *et al.,* 1980) and groundnut (Bindu Joseph, 2000).

2.3. Physiological and biochemical attributes

Potassium as one of the three macronutrient plays a pivotal role in plant growth and other developmental process stimulates assimilation of CO_2 (Cooper *et al*., 1967). Potassium deficiency causes the necrosis in sugar beet leaves it will directly affects the total chlorophyll content (Ulrich and Hills, 1969). Potassium checks the chlorophyll degradation and promotes the synthesis of chlorophyll 'a', chlorophyll 'b' and application of potassium increases the photosynthetic pigments in sugar beet (Li Yu-ying and Liang Hong, 1997) facilitated the transport of iron to shoot apices resulting in an increase the chlorophyll content in tomato (Jolley and brown, 1986).

Boron deficiency decreased leaf chlorophyll content in cotton due to the necrosis symptom of low boron in plant (Zhao Duli and Oosterhuis, 2000). Foliar application of Br increases chlorophyll content in bean plants (Krizek and Mandava, 1983).

About 50 % of the total soluble protein content in leaf extract is accounted for RuBP carboxylase (Ellis, 1976). Potassium deficiency alters many biochemical changes in sugar beet, like CHO metabolism, reduction in photosynthetic rate. Potassium increases the efficiency of enzyme involved in CHO and nucleic acid metabolism because potassium is a cofactor for 40 enzymes (Evans and Sorger, 1966). Low availability of Potassium in plants inhibits the protein synthesis (Webster and Varner, 1954). Potassium application increases the gas exchange through stomatal regulation and there by improve the photosynthetic rates in plants (Fujino, 1967), stimulate the energy production i.e. ATP influencing both photophosphorylation and enzymatic phosphorylation (Jongenderf and Eribe, 1967), improves plant photosynthetic capacity and translocation of photosynthesis, also involved in better assimilate partitioning to the sink (Fei-Hu-Liu and Nancy Longnecker, 1973). Deficiency of K markedly reduced both the quantity and distances that photosynthates moved from sources (Ashtey and Goodson, 1972).

Foliar application of KCl on sugar beet increased the CHO metabolism and increased sucrose synthase activity on leaf (Zehler *et al.,* 1981). Liberal supply of potassium was a key factor for increasing sink capacity and photosynthesis (Tsuno and Fujis, 1968).

The soluble protein content fall from 40 to 25 per cent of control values in boron deficient plants (Desiraja *et al.,* 1993). Boron deficiency decreased leaf photosynthetic rate and carbohydrate transport from leaves to fruits, (Zhao Duli and Oosterhuis, 2000). Boron is needed for the conversion of CHO into protein, if it deficit in plants caused poor accumulation of CHO and decreased protein content in plants (Purvis, 1939).

Brassinolides spray (0.5 ppm) increased the photochemical efficiency and rubisco activity with ultimate result in high yield (Maibangasa *et al.,* 2000), increased the leaf soluble protein content in ground nut (Vardhini and Rao, 1998).

Potassium activates at least 60 different enzymes involved in plant growth. The K changes the physical shape of the enzyme molecule, exposing the appropriate chemically active sites for reaction. Potassium also neutralizes various organic anions and other compounds within the plant, helping to stabilize pH between 7.0 and 8.0, optimum for most enzyme reactions. The amount of K present in the cell determines how many of the enzymes can be activated and the rates at which chemical reactions can proceed. Thus, the rate of a given reaction is controlled by the rate at which K enters the cell (Nelson and Smith, 1969).

The enzyme responsible for synthesis of starch (starch synthetase) is activated by K. Thus, with inadequate K, the level of starch declines while soluble carbohydrates and N compounds accumulate. Photosynthetic activity also affects the rate of sugar formation for ultimate starch production. Under high K levels, starch is efficiently moved from sites of production to storage organs (Suyamto, 1998). Potassium is required for every major step of protein synthesis. The reading of the genetic code in plant cells to produce proteins and enzymes that regulate all growth processes would be impossible without adequate K. When plants are deficient in K, proteins are not synthesized despite an abundance of available nitrogen (N). Instead, protein "raw materials" (precursors) such as amino acids, amides and nitrate accumulate.

The enzyme nitrate reductase catalyzes the formation of proteins, and K is likely responsible for its activation and synthesis (Suyamto, 1998). Application of KCl on sugar beet increased the CHO metabolism and also increased sucrose synthase activity on leaf (Zehler, et *al*., 1981). Assimilates produced by photosynthesis in the leaves are transported in the phloem sap to other organs of the plant, notably to the storage organs (fruits, grains, tubers, etc.). The flow of organic compounds from the "source" to the "sink" is faster in plants when adequately provided with K (Boote *et al.*, 1978). Application of potash increases the Invertase activity in sugarcane (Borden, 1937).

The total and reducing sugars were increased by application of boron along with zinc in plum (*Prunus salicina* Lindl.) plants (Gutieerrez, 1995). Brassinolide application increased the content of reducing sugar content in leaves 106 per cent per leaf and 30 per cent per gram fresh weight in wheat (Braun and Wild., 1984). Brassinosteroids treatment Enhancement of the photosynthetic capacity and translocation of photo assimilates (Sala and Sala, 1985; Bellincampi and Morpurg, 1988). Brassinolide 0.5 ppm spray increased the photochemical efficiency and rubisco activity with ultimate result in high yield (Maibangasa *et al.,* 2000). Brassinosteroids increased shoot and root growth compared with untreated controls. This was associated with increased levels of DNA, RNA, soluble proteins and various carbohydrate fractions (Vardhini and Rao, 1998).

Boron is needed for the conversion of carbohydrate (CHO) in to protein. Boron deficiency caused accumulation of CHO and decreased protein content in plants (Purvis. 1939). Boron enhances the up take and transport of sugars in plants and play a vital role in sugar translocation in sugar beet (Russell *et al.*, 1969). Plant has low B, affects sugar transport in plants, flowers retention, pollen formation and seed germination (Ecochem, 1993). Boron deficiency decreased leaf photosynthesis rate and carbohydrate transport from leaves to bolls in cotton (Zhao DuLi and Osterhvis, 2000). Low protein and lipid content in tomato and okra (DeSiraju *et al*., 1993), affect the growth and physiology of cotton (Qosterhuis and Zhao, 2002). Boron related to metabolism of phenols, hormones, carbohydrates, lignin and development of plant organs (Wu and Wei, 1994). Boron has been recognized since 1923 as an essential micronutrient element for higher plants. Over the years, many roles for boron in plants have been proposed, including functions in sugar transport, cell wall synthesis and lignification, cell wall structure, carbohydrate metabolism, RNA metabolism, respiration, indole acetic acid metabolism, phenol metabolism and membrane transport (Blevins *et al.,* 1994).

Boron deficiency causes many anatomical, physiological and biochemical changes (Barry *et al.*, 1995). Boron has regulatory roles in carbohydrate synthesis and cell division of grapes (Brewbaker, 1998), increased higher sucrose content in the cane juice (Porokhnevich, 1973) and although B is not a constituent of enzymes in plant, nor is there evidence that it directly affects enzyme activities (Parr and Loughman, 1983). It is essential movement of sugars and starches to developing parts (Reeve *et al.*, 1944). The total and reducing sugars were increased by application boron along with zinc (Kersten *et al.,* 1993). Physiochemical characters of fruits generally improved when Zn, Mg and B were applied singly and significantly (Bagali *et al.*, 1992).

2.4. Yield and yield components

The first prerequisite for high yields is an increase in the total dry matter production per unit area. Carbon compounds accounts for 80 - 90 per cent of the total dry matter produced by the plants. It is evident that photosynthetic process is the basis for the building up of organic substances and ultimate dry matter production (Arnon, 1975). The partitioning of dry matter between reproductive and vegetative part is very well expressed by the harvest index (HI), economical yield was not always closely related with biological yield because inefficient partitioning. This measurement of harvest index would help to identify and define the translocation pattern and partitioning potential (Wallace, 1976). Sugar beet is classified as a plant that has a high requirement for K^+, and more K^+ is absorbed by sugar beet than any other mineral nutrient element (Schmehl, and James, 1969). Foliar feeding of K^+ in soybean increases in seed yield (Boote *et al.*, 1978). Application of K^+ increases the root surface in sugar beet (Hallmark and Barber, 1981). Sugar beet well supplied with potassium has a large leaf area to produce more amounts of sugars (high photosynthetic rate due larger leaf area), lack of potassium leads to severe wilting of plants. In sugar beet high K uptake increases the sugar yield (Milford *et al.,* 2000). Soil application of potassium increase beet yield, sugar content and sugar yield reported in sugar beet (Kapur, 1995; Li Yu-ying and Liang Hong, 1997). In sugar beet optimizing K_2O increase sugar yield (Ovidio Pérez and Mario Melgar, 2000).

Application of potassium along with nitrogen increase the plant height, root weight and root yield in cassava (Suyamto, 1998). Potassium plays significant roles in enhancing crop quality. High levels of available K improve the physical and chemical quality, disease resistance (Suyamto, 1998), increased the root length root diameter and total plant weight and yield in beet root (Sayed Mabdel Aal, 1990). K_2O application up to 60 kg ha^{-1} in low potassium soils and 30 kg ha^{-1} on medium K soils to get higher tuber yield in sugar beet (Kapur, 1995). Root weight of black gram was significantly increased following the increased soil application of K along with boron (Singh and Badhoria, 1984). Harvest index of ground nut increased by soil application of K (Gutstein, 1979). Application of KCl at the rate of 200 kg K_20 ha^{-1} increases the sugar content and improves the juice purity in sugar cane (Gruneberg, 1961). Sweet potato responded favourably to potassium nutrition upto 60 Kg K_2O ha^{-1} for better yield (13.64 t ha^{-1}) (Chakrabarty *et al*., 1983). Potassium increased the cane production (CV Co 1148) and sugar yield significantly as a result of improvement in the length of cane, its thickness and weight (Yadav *et al*., 1986), better juice quality and increased sugar production (Hunsigi, 1977). The number and size of tubers increased by nitrogen and potassium applications in cassava (Ashokan and Vikraman Nair, 1984). Growth and yield components of cassava (*viz.,* height of plant, girth of stem, length of petiole, number of leaves shed and retained till harvest, number of tubers, length and girth of tubers, dry matter content of flesh and rind, rind content of tuber and crude fibre content of tubers) directly or indirectly influenced by application of potassium (Nair and Aiyer, 1985). There was a positive relationship between stem girth and level of potassium. Maximum girth of stem was recorded by potash @ 200 kg K_2O ha^{-1}. Potassium deficiency was characterised by thin stems in cassava, the length and girth of tubers generally increased as the levels of potassium increased (Krishnan and Lakshmi, 1972). Potassium deficiency affects the tuber size and yield of sugar beet (Graham and Albert Ulrich, 1972).

Application of potash tended to increase the moisture content and thus rendered cane plant more succulent (Bose, 1948). Boron deficient plants may be stunted; it affects the root growth in sugar beet (Russell *et al.,* 1969). Application of boron and phosphate overcome internal browning in Japanese radish (Kawai et al., 1993). Under drought condition use of boron containing fertilizer in sugar beet increasing sugar yield. Foliar application of boron increases the numbers of the branches and pods in soybean; application of boron along with iron increases the curd yield in cauliflower (Singh and Dixit, 1974). Foliar spray with boron increases the yield and quality of groundnut on lateritic soil (Mahajan *et al.,* 1994). Boron deficiency in crops is more wide spread than deficiency of any other micronutrient. Nutritional disorders in vegetables include brown heart in rutabaga, turnip and radish roots, and hollow stem in cauliflower and broccoli (Barry *et al.,* 1995). Boron in the fertilizer has dramatically reduced several common nutritional disorders such as brown-heart, canker, low fruit set, and other physiological diseases affecting Marketability. A wide range of vegetable crops responds to boron fertilization with increased yields and quality. Boron is essential for normal growth and production of sound, healthy vegetables. Boron has been linked with initiation and development of growing points, movement of sugars and starches to developing parts, movement of nutrient elements within the plant, formation of plant hormones affecting growth, root growth and health of fleshy roots, flower and fruit set, vegetable quality and flavor (Prince and Bear, 1944).

Potassium and boron are most important for potato quality and tonnage. Potassium produces sugars and starch that not only increase the specific gravity of tubers but also fill and increase tuber size. If a potato crop has two or three sets of tubers, potassium helps size the smaller tubers and therefore improves pack-out. Boron increases the translocation of sugars to developing tubers, calcium uptake and movement, and improves the skin strength and disease resistance of tomatoes. Balanced nutrition is the key to improving quality without compromising yield, and both potassium and boron are extremely important nutrients in this respect (Steven Brooks, 1989). The main benefits of boron are, increased root yield, increased sugar content, better juice purity and crop health and resistance to fungus attacks and drought (Brandelburg 1931). Application of Boron at 2 ppm as H_3BO_3 increases the fruit yield and fruit size (Oyewole and Advayi, 1992), the addition of B to a soil limed to pH 7.2 increased yields by 18 % and also improved the shape and uniformity of ripening (Adams and Winzor, 1974). The root formation was found to be directly dependent on available boron (Dhawan and Dhand, 1960). Application of B in deficient areas will ameliorate possible growth problems and improve lint yield in cotton (Qosterhuis and Zhao, 2002). In a field experiment on cauliflower, conducted during the Rabi season of 1988-1989 and 1989-1990, application of Boron along with Fe increased the curd yield (Singh and Dixit, 1994). Both the soil and foliar applied treatments increased yields and fruit quality (Gyul'akhmedov and Gasanova, 1990). Application of boron increased the number of leaves/plant, dry matter content and curd yield (Thakur, *et al.*, 1991), also B improved the chemical composition and fiber quality of ramie (*Boehmeria) (*Pi *et al.*, 1993). Combined application of Zn + Mg + B increased the fruit length, diameter and diameter of the seed cavity and the fruit weight significantly guava (Bagali *et al.*, 1992). Application of B or Mn increased sugar and root yields compared with the untreated control. Mixed application of B + Mn produced the highest root and sugar yields (Hassanin and Abuldahab, 1991). Among the methods tested foliar application of borax 2.5 kg ha^{-1} gave the highest yield and net additional income in tomato (Chowdhary and Amrendra Kumar, 1997).

Brassinolide increases the root growth and enhanced root mass in *Pinus radiate* (Sasse, 1994). Increased root biomass of sugar beet (Schilling *et al.*, 1991), improves the yield of lettuce, radish, bush bean and pepper (Meudt *et al.*, 1984).

Foliar spray of Br substantially improved the yield of wheat and mustard, rice, corn, tobacco, watermelon, cucumber and grape and tobacco (Yokota *et al.*, 1982), increase size and quantity of fruits, improving the content of nutritive components and fruit quality, increase in yield (Sala and Sala, 1985; Bellincampi and Morpurg, 1988). Field trials showed an increase in yield and an improvement in the quality of crops of barley, oat, potato, winter rye and wheat (Pirogovskaya *et al*., 1996). The Br treatment significantly increased yields of several field crops including mustard, groundnut, tomato and potato (Vardhini and Rao, 1998). Foliar application of synthetic steroid DAA-6 increased stem diameter, leaf length and width in tobacco (Diz *et al.*, 1990). The beneficial effect of a synthetic Br is having beneficial effect in ameliorating mild stress in sugarbeet and also improve the yield, quality and sugar content (Schilling *et al.*, 1991).

CHAPTER III

MATERIALS AND METHODS

The present investigations were carried out in *Kharif* during July 2006 at the Field No. NA3, Eastern block, Tamil Nadu Agricultural University, Coimbatore with the objectives of role of nutrients and plant growth regulators in assimilate partitioning in tropical sugar beet, enhancing tuber quality by improving assimilate partitioning through transport facilitators and CO_2 assimilation activators. The nutrients *viz.*, potassium and boron and plant growth regulator Brassinolide were used. The details of materials and methodologies adopted in the present study are presented.

3.1. Materials

3.1.1. Field location

The field experiment was conducted at Field No. NA3 of Eastern block, Tamil Nadu Agricultural University, Coimbatore 3.

3.1.2. Soil characteristics

The soil of the experimental site was analysed for the various physical and chemical characteristics before the start of the experiment and data are present in Table 1.

3.1.3. Weather parameters

Meteorological data pertaining to maximum and minimum temperature, solar radiation, relative humidity, evaporation rate and total rainfall were collected from the meteorological observatory of Tamil Nadu Agricultural University, Coimbatore (Table 2).

3.1.4. Cultivar employed

The Indus cultivar of tropical sugar beet variety having duration 150-160 days was used for the experiment

3.2. Methods

3.2.1. Cultivation details

3.2.1.1. Experimental design

Details of the design adopted are summarized below:

Design of experiment	:	Randomized block design (RBD)
Replications	:	Three
Treatments	:	Ten

T_1	:	Control
T_2	:	KCl 1 % spray- 50 DAS
T_3	:	KCl 1 % spray – 50 & 75 DAS
T_4	:	Boric acid 0.5 % spray - 50 DAS
T_5	:	Boric acid 0.5 % spray – 50 & 75 DAS
T_6	:	Brassinolide 0.5 ppm spray- 50 DAS
T_7	:	Brassinolide 0.5 ppm spray – 50 & 75 DAS
T_8	:	KCl 1 % + boric acid 0.5% + brassinolide 0.5 ppm spray - 50 DAS
T_9	:	KCl 1 % + boric acid 0.5 % + brassinolide 0.5 ppm spray – 50 & 75 DAS
T_{10}	:	KCl 1 % + boric acid 0.5 % – 50 & 75 DAS

Plot size	:	5 m x 4 m
Spacing	:	50 cm x 20 cm
Date of sowing	:	14.07.2006
Date of harvesting	:	16.12.2006

3.2.1.2. Experimental procedure

The experimental field was prepared and farm yard manure at 12.5 t ha^{-1} was incorporated into the soil. Normal agronomic practices and recommended fertilizer doses of 150, 75, and 75 kg ha^{-1} nitrogen, phosphorous and potassium were applied basally along with sides of the ridges.

The treatments involved were sprays of nutrients and plant growth regulators imposed as per schedule.

3.2.2. Observations

3.2.2.1. Morphological traits

The following morphological parameters at the selected growth stages *viz.*, 60, 90, 120 and 150 days after sowing were recorded. Five random samples were taken from each replication in each treatment for recording the observations.

3.2.2.1.1. Plant height

The plant height measured from the ground level to the growing tip at different stages and mean was worked out and expressed in cm.

3.2.2.1.2. Leaf number

Five plants for each replication of each treatment were selected and the leaf number was counted as a single unit. The number of leaves per plant was presented by calculating the mean of five plants.

3.2.2.2. Growth analysis

3.2.2.2.1. Leaf area & Leaf area index (LAI)

Leaf area was measured by leaf area meter (Model L1-3100 of Inc., Lincoln, and Nebrask, USA) and expressed as cm^2 per plant. The leaf area index was calculated by employing the formula of Williams (1946)

$$LAI = \frac{\text{Leaf area per plant}}{\text{Ground area occupied per plant}}$$

3.2.2.2.2. Leaf area duration (LAD)

Leaf area duration was determined by using the formula of Kvet *et al.* (1971) and the values were expressed in days.

$$LAD = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

L_1	-	LAI at first stage
L_2	-	LAI at second stage
$(t_2 - t_1)$	-	Time interval in days between stages

3.2.2.2.3. Leaf area ratio (LAR)

Leaf area ratio was arrived at by employing the formula given by Radford (1967) and the values expressed in $cm^2 g^{-1}$.

$$\text{LAR} = \frac{\text{Leaf area per plant}}{\text{Total plant dry weight}}$$

3.2.2.2.4. Specific leaf weight (SLW)

Specific leaf weight was calculated by employing the following formula of Pearce *et al.* (1968) and expressed in mg cm^{-2}.

$$\text{SLW} = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

3.2.2.2.5. Dry weight of leaf and root

At each stage, three plants were pulled out from each plots washed thoroughly, and dried in oven at 85 ± 1^0C. The weight of leaves and roots per plant was recorded and the average was expressed in cm.

3.2.2.2.6. Relative growth rate (RGR)

The relative growth rate was calculated by using the formula suggested by Williams (1946) and expressed in mg g^{-1} day^{-1}.

$$\text{RGR} = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{(t_2 - t_1)}$$

W_1 and W_2 - Whole plant dry weight at t_1 and t_2 respectively

$t_2 - t_1$ - Time interval in days

3.2.2.2.7. Net assimilation rate (NAR)

The method proposed by Williams (1946) was employed for measuring NAR on leaf area basis and the values were expressed in mg cm^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{Log_e L_2 - Log_e L_1}{L_2 - L_1}$$

W_1 and W_2	-	Dry weight of whole plant at t_1 and t_2, respectively
L_1 and L_2	-	Leaf area at t_1 and t_2, respectively
$t_2 - t_1$	-	Time interval in days

3.2.2.2.8. Crop growth rate (CGR)

The crop growth was estimated by using the formula of Watson (1956) and expressed in g m^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

W_1 and W_2	-	Whole plant dry weight at t_1 and t_2, respectively
$t_2 - t_1$	-	Time interval in days
P	-	Ground area occupied by the plant (m^2)

3.2.2.3. Biochemical parameters

3.2.2.3.1. Chlorophyll content

Total chlorophyll, chlorophyll ‘a’ and chlorophyll ‘b’ were estimated in a fully expanded leaf from the each plant at specified phenophases by adopting the procedure of Yoshida *et al.* (1972) and contents was expressed on fresh weight basis as mg g^{-1}.

3.2.2.3.2. Soluble protein content

Soluble protein content was estimated from the alcohol extract of leaf following the method described by Lowry *et al.* (1951) and expressed as mg g^{-1} fresh weight.

3.2.2.3.3. Invertase

Invertase enzyme was assayed at 60, 90, 120 and 150 DAS. A tuber sample of each treatment from each replication was cut, stripped and topped. Prechilled disc (1 g) from tuber was treated with 5 ml cold ethyl acetate for 20 minutes. Ethyl acetate after treatment was decanted and the discs were washed with distilled water still the smell goes off. Invertase activity was estimated in a reaction mixture (10 ml) containing 0.05 M citrate buffer (pH 5) for acid invertase or 0.05 M sodium phosphate buffer (pH 7) for neutral invertase. 0.2 M sucrose (BDG, Poole, U.K.), distilled water and 0.1 ml of toluene along with stem discs (1 g). The tubes were incubated at 30^0C and reducing sugar was estimated using aresenomolybdate reagent at the intervals of 15 and 45 minutes. The amount of reducing sugar formed was quantified against standard curve prepared with known concentrations of glucose in identical experimental conditions and expresses as μmol g^{-1} fw h^{-1}.

3.2.2.3.4. Sucrose synthase

Fully opened fresh leaves of sugar beet were dribbled and were cut into small bits and grained with 5 ml of cold phosphate buffer (pH 7) containing 20 mM β-mercaptoethanol using pre-chilled pestle and mortar. The filtrate was centrifuged at 10,000 rpm for 15 minutes. The resultant supernatant was used for estimating SPS and SS. The reaction mixture in 2 ml contained Tris Hcl (0.7 ml), fructose-6-phosphate (0.2 ml) for SPS or fructose (0.2 ml) for SS. $MgCl_2$ (0.2 ml), UDPG (0.2 ml), NAF (0.2 ml) for SPS or distilled water for SS and 0.5 ml of enzyme extract. The tubes were incubated at 30 ^{0}C and aliquots taken at 0 and 30 minutes were used for estimation using Aresenomolybdate reagent. The amount of sucrose formed was quantified against a standard curve prepared with known concentrations of glucose in identical experimental conditions and expresses as μmol g^{-1} fw h^{-1}.

3.2.2.3.5. Reducing sugars

The reducing sugars was estimated from ethanol soluble aliquot (Somogyi, 1952) and the content was expressed as mg g^{-1} fresh weight.

3.2.2.3.6. Total sugars

The total sugars content was estimated from leaves and tubers by the method of Somogyi (1952) and the values were expressed as mg g^{-1} fresh weight.

3.2.2.3.7. Non-reducing sugars

The Non-reducing sugar content was derived from subtract of reducing sugars from total sugars and the values were expressed as mg g^{-1} fresh weight.

3.2.2.3.8. TSS

The total soluble solids of the tubers estimated by using the Refracto meter and the values were expressed as °Brix.

3.2.2.4. Yield and yield attributes

2.2.2.4.1. Tuber length

The tuber length was measured from the top to root tip at different stages and mean was worked out and expressed in cm.

3.2.2.4.2. Tuber girth

Tuber girth measured at maximum girth area of each tuber at different stages and mean was worked out and expressed in cm.

3.2.2.4.3. Tuber fresh Weight

The weight of the each tuber measured at different stages and mean was worked out and expressed in g plant^{-1}.

3.2.2.4.4. Moisture content (%)

$$\text{Moisture content (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

W_1 = Initial fresh weight W_2 = Final dry weight

3.2.2.4.5. Harvest index (HI)

Harvest index was calculated by employing the following formula of Yoshida *et al.* (1972) and expressed as percentage.

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.2.4.6. Benefit: cost ratio

Benefit: cost ratio was calculated for each treatment based on the prevailing cost of cultivation charges and cost of nutrients and plant growth regulator.

3.2.2.5. Statistical Analysis

The statistical analysis was done for all the parameters as suggested by Panse and Sukhatme (1961) to bring out differences among the stages and treatments. All the statiscal analysis was done in personal computer by using package AGRES.

Table 1. Physico – Chemical properties of the experiment field

Characters	
Mechanical analysis (Piper, 1950)	
Clay (%)	27.90
Silt (%)	16.10
Fine sand (%)	18.30
Course sand (%)	33.70
Bulk density	1.40
Chemical analysis	
Organic carbon	0.42
Available N (kg ha^{-1}) (Subbaiah and Asija, 1956)	215.00
Available P (kg ha^{-1}) (Olsen *et al.*, 1954)	11.30
Available K (kg ha^{-1}) (Standfird and English, 1949)	290.00
PA (1:2 Soil water extract)	7.90
EC (dsm^2) (1:2 Soil water extract)	0.40

Table 2 Weather data (July – December 2006)

Std week	Temperature (^0C)		Relative humidity (%)		Evaporation (mm)	Rainfall (cm)	Sunshine hours	Solar radiation cal cm^{-2} day^{-1}
	Max.	Min.	0722 hrs	1422 hrs				
28	31.2	23.8	75	53	7.7	-	5.9	382.4
29	32.0	24.7	75	47	8.8	0.2	8.4	433.2
30	31.4	23.0	79	49	6.6	1.0	4.7	344.2
31	31.7	22.5	79	53	6.8	1.8	5.5	374.1
32	31.7	23.1	77	50	7.0	2.8	5.9	362.9
33	31.4	23.8	74	53	7.7	3.2	6.6	374.7
34	32.1	22.8	91	48	5.0	3.0	5.7	370.4
35	32.4	21.3	87	60	6.3	-	7.8	379.2
36	31.8	22.8	94	65	3.7	45.5	6.0	330.0
37	29.9	22.9	83	63	5.4	6.6	4.5	307.5
38	29.1	22.7	82	53	4.4	9.2	3.4	268.5
39	31.3	22.1	88	49	5.7	8.0	6.6	365.4
40	32.3	21.4	88	56	6.4	-	10.1	447.1
41	31.4	23.1	89	59	4.6	43.4	5.2	323.4
42	30.9	23.0	91	69	3.9	52.8	5.4	350.9
43	29.0	22.2	91	71	3.1	30.0	2.4	273.3

44	28.5	21.8	94	70	2.4	173.0	4.0	293.6
45	27.9	21.7	96	68	2.7	139.9	3.3	296.1
46	28.8	22.2	92	69	3.0	14.5	5.5	347.7
47	27.9	22.0	94	58	2.4	45.0	3.3	256.6
48	28.8	21.6	94	47	2.9	0.4	6.4	378.3
49	28.4	18.6	89	53	3.6	-	7.8	441.0
50	28.9	20.1	89	48	3.9	0.6	7.1	399.9
51	28.5	18.7	88	44	4.5	-	7.3	450.0
52	28.7	17.9	91	46	3.9	0.6	7.5	438.5

CHAPTER IV

EXPERIMENTAL RESULTS

A field experiment was carried out to evaluate the impact of foliar feeding of nutrients and plant growth regulator on morphological, physiological, biochemical, yield components and yield of tropical sugar beet. The experiment was conducted at Eastern Block, Tamil Nadu Agricultural University, Coimbatore during July – December 2006. The nutrients like potassium and boron, plant growth regulators like Brassinolide were sprayed through foliage individually and in combination. Morphological and growth characters, physiological and biochemical components were recorded at different growth stages (60, 70, 120 and 150 DAS) of tropical sugar beet. The results of the experiment are presented in this chapter.

4.1. Morphological traits

4.1.1. Plant height (cm)

The time trend of growth of sugar beet in terms of plant height as influenced by foliar spray of nutrients and plant growth regulator is given in Table 3. The results revealed that there was a rapid increase in height of the plant from 60 days after sowing (DAS) to 90 DAS followed by a static growth up to 120 DAS and a decline there after. All the spray treatments showed significant effect on increasing the height of the plant at different stages. Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded the highest values in all the growth stages (27.5, 40.9, 42.1 35.3), and this was closely by followed by combination spray of KCl 1 % and boric acid 0.5 % given on 50 and 75 DAS (T_{10}) treatment (25.8, 39.9, 40.8 and 33.9). At rapid growth period (90 DAS), T_3 was (38.2) on par with T_7. At 120 DAS, T_7 closely followed T_9 out performing T_{10} and all the other treatments had significant effect on plant height over control.

4.1.2. Number of leaves (Number plant^{-1})

The leaves number increased up to 120 DAS and declined thereafter irrespective of treatments **(**Table 4). Active leaf number was more at 120 DAS in all the treatments. Among the treatments combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) had more number of leaves. It recorded 19.6, 26.1, 27.1 and 13.7 at the stages of 60, 90, 120 and 150 DAS respectively and this was followed by combination spray of KCl 1 % and boric acid 0.5 % given on 50 and 75 DAS (T_{10}) treatment (19.4, 25.9, 26.3 and 13.5) at al the growth stages. At 150 DAS, T_3 was on par with $T_{7,}$ and also at 120 DAS, T_3, T_9 and T_7 were on par with each other.

4.1.3. Leaf area (cm^2 plant^{-1})

Leaf area was found to be increasing from 60 DAS to 120 DAS and decline there after towards the maturity of the crop (Table 5). All the treatments showed significant differences in leaf area at all the growth stages; irrespective of the treatments leaf area was the maximum at 120 DAS (5525.6 – 6130.9). Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded the largest leaf area of 4560.6, 5834.4, 6130.9 and 1361.0 at 60, 90, 120 and 150 DAS respectively, and it was followed by combination spray of KCl 1 %

and boric acid 0.5 % given on 50 and 75 DAS (T_{10}) treatment (4543.8, 5747, 6042.5 and 1244.7) at all the stages. At 90 DAS, T_5, T_3 and T_7 were on par with each other.

4.2. Growth attributes

4.2.1. Leaf area Index

Leaf area index followed the same trend as that of leaf area (Table. 6). Maximum LAI was recorded at 120 DAS in all the treatments (6.02 – 6.46) and there was a decline in LAI towards the maturity (0.66 – 0.80). Significant differences were noticed in all the treatments at all growth stages. Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded the maximum LAI (4.83, 5.95, 6.46 and 0.80) at all the stages. This was followed by T_{10} which recorded the LAI values of 4.75, 5.68, 6.41 and 0.78 at the stages of 60, 90, 120 and 150 DAS respectively. At 90 and 120 DAS, T_{10} was on par with T_8.

4.2.2. Specific leaf weight (mg cm^2)

Specific leaf weight showed on increasing trend from 60 DAS to 120 DAS (Table 7) At 150 DAS, a decline in SLW was noticed. There was a significant difference in the trend of SLW due to the spray treatments. Combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9), recorded the highest SLW of 4.98, 7.85, 9.09 and 6.33 at 60, 90, 120 and 150 DAS respectively, and it was followed by T_{10} (4.96, 7.59, 8.80 and 6.15). The treatments T_3, T_5, T_7, T_2 and T_4 were on par at 120 and 150 DAS.

4.2.3. Leaf area duration (days)

Leaf area duration was determined by adopting the values of leaf area index obtained during various stages of crop growth **(**Table 8). LAD increased and reached maximum between 90 - 120 DAS and there after gradual decline in the parameter was noted. LAD values were significantly superior in all the spray treatments (168.1 – 186.2) between 90 -120 DAS and this indicating the retention of green leaves for a longer period over control. Among the treatment, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded maximum LAD (186.2) and this was closely followed by T_{10} (185.4) between 90 - 120 DAS. The treatments T_5, T_3 and T_7; T_2, T_4 and T_6 were on par with each other between 90 - 120 and 120 – 150 DAS.

4.2.4. Total dry matter production (g plant^{-1})

The total dry matter production (TDMP) recorded a progressive increase with the growth of the plant reaching its maximum total biomass at harvest **(**Table 9). The TDMP at all the stages differed significantly. The highest value (150.3 – 171.0) recorded at 150 DAS in all the treatments. All foliar treatments produced higher total dry weight as compared to control. Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded maximum TDMP (33.7, 80.5, 137.4 and 171.0) at all the growth stages. This was closely followed by T_{10} (33.1, 78.3, 134.6 and 166.3). At 150 DAS, T_3 was on par with T_7.

4.2.5. Crop growth rate (g m^{-2} day^{-1})

Crop growth rate considered as the deciding factor in predicting the photosynthetic performance of the plants at field level indicated a gradual increase from 60 to 90 DAS followed by a rapid rise during 90 to 120 DAS and a gradual decline up to 150 DAS (Table 10). Significant differences were observed in all the spray treatments at all the growth stages. Between 90 - 120 DAS, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded maximum CGR (19.34) and this was followed by combined spray of 1 % KCl and 0.5 % boric acid given on 60 and 90 DAS.

4.2.6. Relative growth rate (mg g^{-1} day^{-1})

The RGR was higher (138.4 – 153.2) between 90 - 120 DAS and drastically reduced (41.6 – 49.4) towards harvest **(**Table 11). All the treatments showed a significant increase in RGR over unsprayed control. Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded the maximum RGR (153.2) at 120 DAS, and it was followed by T_{10} (148.5) at 120 DAS.

4.2.7. Net Assimilation Rate (mg cm^{-2} day^{-1})

The NAR showed a steep increase from 60 - 90 DAS to 90 - 120 DAS and there after decline towards 120 - 150 DAS (Table 12). Irrespective of the treatments the stage 90 - 120 DAS recorded maximum NAR (0.43 – 0.53). Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded the maximum NAR (0.53) between 90 - 120 DAS, this was closely followed by T_{10} (0.51), and T_8 (0.50) at 90 - 120 DAS, and also these treatments (T_{10} and T_8) were on par with each other between 90 - 120 DAS.

4.3. Physiological and biochemical traits

4.3.1. Chlorophyll content (mg g^{-1}fw)

Total chlorophyll content as well as chlorophyll components *viz.*, chlorophyll 'a' and chlorophyll 'b' were found to be enhanced by nutrients and plant growth regulator in sugar beet **(**Tables 13, 14 and 15). There was gradual increase in total chlorophyll content from 60 DAS, recording maximum at 120 DAS (2.265 – 2.374) in all the treatments. There after the total chlorophyll content gradually decreased (0.820 – 0.870) towards maturity. Combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded highest chlorophyll content (1.708, 2.374) at 90 and 120 DAS and it was closely followed by combined spray of KCl 1 % and boric acid 0.5 % given on 50 and 75 DAS (T_{10}).

On comparing the chlorophyll 'a' content at different growth stages, it was seen that chlorophyll 'a' followed the same trend as that of total chlorophyll with maximum value at 120 DAS, and thereafter decline towards maturity in all the treatments. At 90 and 120 DAS, the maximum chlorophyll 'a' recorded in combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) treatment (1.308, 1.621) this was followed by treatment T_{10} (1.302, 1.617).

Nutrients and plant growth regulator enhanced chlorophyll ‘b’ content also in sugar beet, all the treatment were significantly higher compared with unsprayed control. All the treatment showed an increase in chlorophyll ‘b’ content (0.728 – 0.766) until 120 DAS, and there after it decreased drastically (0.173 – 0.191) towards maturity. Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded the highest chlorophyll ‘b’ content (0.403, 0.766) at 90 and 120 DAS. It was followed by T_{10} (0.398, 0.761). At 90 DAS, treatments T_8, T_5, T_3 and T_7 were on par with each other.

4.3.2. Soluble protein (mg g^{-1} fw)

The effect of nutrients and plant growth regulator on soluble protein content was studied and the results obtained showed that soluble protein content increased from 60 to 120 DAS and it decreased at 150 DAS in all the treatments (Table 16). Irrespective of the treatments at 120 DAS recorded maximum soluble protein content (12.83 – 15.05) in all the treatments. Combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded maximum soluble protein content (8.98, 12.14, 15.05 and 6.91) at 60, 90, 120 and 150 DAS respectively. This was followed by T_{10} (8.74, 11.45, 14.60 and 6.71) at all the growth stages. At 120 DAS, treatments T_3, T_5 and T_7 were on par with each other.

4.3.4. Sucrose synthase (μmol g^{-1} fw h^{-1})

Results obtained from the experiment showed that the foliar spray of nutrients and plant growth regulator treatment increased the activity of sucrose synthase enzyme in sugar beet with a gradual increase in the enzyme activity from 60 to 120 DAS and thereafter decreased abruptly at the 150 DAS (Table 17). All the treatments recorded maximum enzyme activity at 90 and 120 DAS. Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded highest enzyme activity (13.03, 19.06, 24.45 and 9.72) at 60, 90, 120 and 150 DAS respectively, and it was followed by treatment T_{10} (12.19, 18.36, 23.82 and 8.87) at all the growth stages. At 150 DAS, the treatments T_3, T_5, T_7, T_2 and T_4 was on par with each other. Comparing the enzyme activity at different stages, a significantly high value (21.51 – 24.45) was recorded at 120 DAS.

4.3.4. Invertase (μmol g^{-1} fw h^{-1})

It was observed that the invertase enzyme activity in sugar beet roots decreased drastically at various growth stages from 60 – 150 DAS (Table 18). All the treatments showed a decreasing trend in invertase activity from 60 to 150 DAS. Irrespective of the treatments, the enzyme activity was non significant at 120 and 150 DAS. Although the combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded higher enzyme activity at early stages (60 – 90 DAS) and it was non significant at later stages.

4.3.5. Reducing sugars (mg g^{-1} fw)

The reducing sugar content at various phenophases of sugar beet under the influence of nutrients and plant growth regulator revealed a significant variation in all stages of leaves and in tubers it was non significant at final harvest (Table 19 and 20).

The reducing sugars gradually declined both in leaves and tubers from 60 to 150 DAS. Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded the maximum amount of reducing sugar both in leaves and tuber at all the stages. It recorded 5.19, 2.26, and 1.45 in leaves, and 5.17, 1.86 and 0.53 in roots at 90,120 and 150 DAS respectively. This was followed by treatment T_{10}.

4.3.6. Total sugars (mg g^{-1} fw)

The total sugar content recorded maximum at 90 DAS and sharply declined at 150 DAS in sugar beet leaves (Table 21 and 22). Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded maximum total sugar content (18.16, 10.00 and 4.78) at 90, 120 and 150 DAS respectively. This was closely followed by T_{10} (18.00, 9.96 and 4.60) at all the growth stages.

But in roots, the total sugar content showed an increasing trend up to maturity. The total sugar content recorded maximum values (129.75 – 138.61) in all the treatments at 150 DAS. Combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded highest total sugar content (25.97, 74.94 and 138.61) at all the growth stages, it was followed by treatment T_{10} (25.98, 74.93 and 137.24) at all the growth stages respectively.

4.3.6. Non reducing sugars (mg g^{-1} fw)

Non reducing sugars content of sugar beet leaves recorded maximum at 90 DAS, and there after decline towards maturity (Table 23 and 24). Combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded maximum non reducing sugar content in all the growth stages. It recorded 17.98, 9.90 and 4.73 at 90, 120, and 150 DAS respectively, and this was closely followed by T_{10} (17.79, 9.79 and 4.48) at all the growth stags.

The non reducing sugar content in roots followed the same trend as that of total sugar content in roots. It was gradually increases from 60 DAS up to 150 DAS and recoded maximum at harvesting stage. Among the treatments, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded maximum total sugar content (138.08) at 150 DAS where as T_{10} recorded maximum total sugar content (20.91 and 73.19) in the early stages of tuber growth (90 and 120 DAS)

4.3.7. Total soluble solids (°Brix)

The total soluble solids, the important attribute, determine the quality of the tubers. The TSS content gradually increased up to harvest (Table 25). At harvesting stage, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded maximum TSS content (16.7) over un sprayed control (14.6) and this was closely followed by the combination spray of KCl 1 % and boric acid 0.5 % treatment T_{10} (16.1) at 150 DAS. At 150 DAS treatments, T_3, T_5 and T_6

were on par with each other. Between stages also there was significant difference with 150 DAS recording the highest mean value (15.4).

4.4. Yield and yield components

4.4.1. Tuber length (cm)

Tuber length showed increasing trend up to harvest in all the treatments (Table 26). All foliar spray treatments were superior to control in increasing the tuber length. At 50 and 75 DAS, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded maximum tuber length (21.9, 24.9, 29.3 and 32.8) at 60, 90, 120 and 150 DAS, respectively. This was followed by treatment T_{10} (20.8, 23.9, 28.6 and 31.4) and the treatments T_3, T_5 and T_7 were on par with each other.

4.4.2. Tuber girth (cm)

The girth of the tuber also showed significant variations among the treatments and also from the control (Table 27). It was steadily increased up to harvest. Combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) showed maximum tuber girth (22.4, 31.4, 34.7 and 39.7) at all the growth stages. This was closely followed by T_{10} (22.0, 31.0, 34.1 and 39.0) at 60, 90, 120 and 150 DAS, respectively. At 120 DAS, maximum growth period, T_4 was on par with T_6.

4.4.3. Tuber fresh weight (g plant^{-1})

The tuber weight was important yield parameter in sugar beet. The fresh weight of individual tuber was significantly improved (955.8 – 1124.8) by application of nutrients and growth regulator (Table 28). The fresh weight of the tuber gradually increases up to harvest. At 50 and 75 DAS, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded maximum fresh tuber weight (383.2, 668.2, 868.3 and 1124.8) at 60, 90, 120 and 150 DAS, respectively and it was followed by T_{10} (383.2, 618.0, 823.9 and 1085.3) at all the growth stages.

4.4.4. Moisture content (%)

The foliar spray of nutrients and plant growth regulator cannot influence significant differences in moisture content (Table 29). Although the treatments T_8 recorded maximum (83.7) moisture content and it was closely followed by T_6 (83.6), the treatment effect was non significant among the different treatments.

4.4.5. Yield (t ha^{-1})

Yield of tuber was enhanced by all spray treatments compared to unsprayed control from 59.78 to 65.22 (Table 29). Highest tuber yield per hectare (65.22) was recorded in the combination spray treatment of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9), which was followed by combined spray of KCl 1 % and boric acid 0.5 % given on 50 and 75 DAS (64.34). Control plants recorded the lowest tuber yield (59.78) and yield increase in the above treatments accounted for 9.10 and 7.63 per cent respectively.

4.4.6. Harvest index (%)

Harvest index was significantly improved by combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recording the highest HI (71.94) accounting for 8.11 % increase over control (Table 29). This was followed by combined spray of KCl 1 % and boric acid 0.5 % given on 50 and 75 DAS (70.88) resulting an increase of 6.51 % over control. Control recorded the lowest value (66.55) and all treatments recorded higher HI (66.82 – 71.94) compared to control.

4.4.7. Benefit cost ratio:

Among the various treatments, high net income of Rs. 18,019 was realized by the combination spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS (T_{10}) with a benefit: cost ratio of 1.50 (Table 30). Although, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS (T_9) recorded higher yield than T_9, net income and benefit cost ratio was low (Rs. 17,406 and 1.48 respectively).

CHAPTER V

DISCUSSION

A field experiment was carried out to evaluate the impact of foliar feeding of potassium, boron and brassinolide to improve the growth, development, yield and quality of tropical sugar beet CV. Indus (Plate 1). The data collected on morphological traits, growth attributes, physiological characteristics and biochemical traits at different growth stages (60, 70, 120 and 150 DAS), yield and yield components recorded under different treatments were critically discussed in this chapter.

4.1. Morphological traits

The plant height, leaf number and total leaf area of sugar beet increased with time trend and reached a static growth at 120 DAS and declined at harvest (150 DAS) due to senescence of lower leaves. This trend was maintained for all the treatments. The plant vigour in terms of leaf number, leaf area and plant height was significantly increased by foliar spray of nutrients and plant growth regulator. The results revealed that the most effective treatment, KCl 1 % + boric acid 0.5 % + brassinolide 0.5 ppm spray given on 50 and 75 DAS increased the growth and productivity. The correlation co-efficient for plant vigour in terms of leaf number, area and plant height at different growth stages with yield revealed the importance of leaf area throughout the cropping period (60 – 150 DAS) by recording higher 'r' values in all the stages (0.76 – 0.79); leaf number between 120 and 150 DAS and plant height between 90 – 150 DAS also highly positively related to yield (Table 31). The most effective treatment, KCl 1 % + boric acid

0.5 % + brassinolide 0.5 ppm spray given on 50 and 75 DAS also recorded significantly higher values for the morphological characters of the plant. The next best treatment was the combined nutrient spray of KCl 1 % and boron 0.5 % given twice on 50 and 75 DAS. The beneficial effect of supplementary nutrition of K and B and the steroid hormone, brassinolide on vigour of the plant was well established in several field crops (Nair and Aiyer, 1985; Srivastava and Luthra, 1992; Suyamto, 1998)

4.2. Growth analysis

Leaf area index, an index of photosynthetic surface available for trapping light energy was the maximum at tuber development stage and drastically declined at physiological maturity of the tuber due to senescence of leaves (Fig. 2).The photosynthetic surface recorded at all the stages was significantly increased by foliar spray of nutrients and plant growth regulator. Although all the supplementary sprays of nutrients and plant growth regulator are beneficial in increasing LAI, the combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was identified as significantly superior treatment followed by the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS by recording the maximum values at all growth stages. The supplementary sprays of nutrients and plant growth regulator had beneficial effect through the delayed leaf senescence during tuber development stage. Potassium checks the chlorophyll degradation and promotes the synthesis of chlorophyll ‘a’, chlorophyll ‘b’, increases the photosynthetic pigments in sugar beet (Yu-ying and Liang Hong, 1997); it also facilitated the transport of iron to shoot apices resulting in an increase the chlorophyll content as in tomato (Jolley and brown, 1986). This is evident from the positive correlation coefficient value of 0.70 and 0.65 recorded between LAI and yield during tuber development stage (Table 31).

As the leaf area duration, an indicator for the retention of green leaves over a period was determined by adopting the values of leaf area index and therefore LAD, the same trend had similar beneficial effects due to foliar sprays of nutrients and plant growth regulator. The leaf area duration was 10 to 11 per cent higher than the control in the plants sprayed with combination of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS. The next best identified treatment was the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS. By maintaining higher LAD values on all growth stages, the above treatment is able to register significantly higher yield than control and all other treatments. The importance of LAD, as an important factor for growth and development of crops was well explained by Evans *et al.* (1975). This was evident from the correlation coefficient values recorded between LAD and tuber yield (Table 31).

The specific leaf weight, thickness of the photosynthetic surface, had significant effect on yield (Fig. 3). The correlation coefficient values between SLW and final tuber yield was positive and highly significant during tuber development stage. The SLW showed an increasing trend from 60 DAS to 120 DAS and declined at 150 DAS due to remobilization of photo assimilates from older leaves to the developing tubers. Due to drastic reduction in LAI from 120 to 150 DAS, only few leaves were photosynthetically active and are able to maintain slightly higher SLW values. As in LAI all the supplementary sprays of nutrients and plant growth regulator are found to be beneficial in increasing SLW. However, the combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was identified as significantly superior treatment to others, which recorded the higher values at all growth stages. The next best identified treatment was the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS. This was evident from the significant positive correlation coefficient value of 0.76 and 0.65 recorded between SLW and yield during tuber development stage (Table 31).

The improving leaf development in terms of leaf area, leaf area duration and specific leaf weight is important for increasing photo assimilate production during the active growth phase. In the present study, all the supplementary sprays of nutrients and plant growth regulator had stimulating effect on leaf growth which in turn reflected on increased yield over control. Corroborating findings are available from the studies conducted in other field crops (Li Yu-ying and Liang Hong 1997; Bindu Joseph, 2000).

The prerequisite for high yields is an increase in the total dry matter production per unit land area through the carbon assimilation by photosynthetic process as the carbon compounds alone accounts for more than 80 per cent of total biomass. Sugar beet is basically a crop which accumulates predominantly the carbon compounds as total biomass. The supplementary sprays of nutrients and plant growth regulator had significant and profound effect on total dry matter production (TDMP) at all the stages (Fig. 4). Although all the treatments had their share on increasing total dry matter production, the combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was identified as superior treatment followed by the next best treatment of combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS, since they recorded higher values at all the growth stages. The beneficial effect of increase in total biomass production reflected on tuber yield, positive and significant effect on tuber yield increase in all the treatment was evident from the very high ‘r’ values (0.75 – 0.84) recorded between yield and biomass production.

Among the growth rates, crop growth rate, considered as the deciding factor of photosynthetic performance of the plants at field level, indicated a gradual increase in the early growth stage followed by a rapid rise during active growth phase coincides with high LAI and recorded a gradual decline at physiological maturity stage. The supplementary sprays of nutrients and plant growth regulator had stimulating effect by recording higher CGR at all the growth stages particularly combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS. This treatment was identified as the most efficient treatment, as it recorded higher CGR values than control and other treatment (Fig.5).

The relative growth rate also followed the same trend as that of CGR between control and supplementary sprays of nutrients and plant growth regulator treatments. However the RGR was drastically reduced towards harvest in all the treatments. This may be due to accumulation of more amounts of photo assimilates in tubers rather than in shoots.

The net assimilation rate, a measure of photosynthetic assimilation capacity of leaves was low in the beginning, increased at active growth phase and declined thereafter in all the treatments. The supplementary sprays of nutrients and plant growth regulator had stimulating effect on assimilation potential of leaves by recording higher NAR at all the growth stages particularly combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS, which was the most efficient treatment and recorded higher NAR values than control and other treatments (Fig. 6).

The growth rates, CGR, RGR and NAR were significantly and positively related to yield on all the growth stages (Table 31). It is evident that the tuber yield was greatly depending on growth rates in terms of NAR and CGR. All the supplementary sprays of nutrients and plant growth regulator had stimulating effect on growth rates which in turn reflected on increased yield over control. The sugar beet crop is positively responding to supplementary nutrients and the growth is stimulated by plant growth regulator. Documented evidences are available for the similar stimulatory effect on growth rates by supplementary nutrition of potassium and boron (Gyul'akhmedov and Gasanova, 1990; Hassanin and Abuldahab, 1991; Thakur *et al*., 1991; Mukhopadhyay *et al.,* 1992; Ateeque *et al.,* 1993; Yamagishi and Yamamoto, 1994) and spray of photosynthetic stimulant Brassinolide in several field crops (Wallace *et al*., 1972; Diz *et al.,* 1990; Krizek and Mandava, 1983; Pippatanawong *et al.,* 1996; Bindu Joseph, 2000).

4.3. Physiological and biochemical traits

The amount of light trapped by the leaves is decided by the concentration of total chlorophyll present per unit leaf tissue. Higher the concentration of photosynthetic pigments more the light absorbed by the leaves. The chlorophyll content is one of the measures to assess the photosynthetic efficiency of crop plants. In the present study, the nutrients and plant growth regulator positively enhanced photosynthetic pigments *viz.* chlorophyll 'a' and chlorophyll 'b'. The pigments concentration increased gradually reached the maximum at 120 DAS and decreased at 150 DAS due to senescence process.

Combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given on 50 and 75 DAS was found effective not only in recording highest chlorophyll content at 90 and 120 DAS and also maintaining higher chlorophyll content at 150 DAS with less reduction when compared to other treatments (Fig. 7). The total chlorophyll content was significantly and positively related to yield and the ‘r; value was high (0.70) at 120 DAS (Table 32). Several studies conducted earlier in many field crops revealed that potassium checks the chlorophyll degradation and promotes the synthesis of chlorophylls (Jolley and brown, 1986 and Li Yu-ying and Liang Hong, 1997), boron deficiency decreases leaf chlorophyll content (Bhatia and Kaur, 1997) and foliar application of brassinolide increases chlorophyll content (Vardhini and Rao, 1998; Maibangasa *et al.,* 2000). In the present study also the nutrients potassium and boron and plant growth regulator brassinolide exhibited a positive response in terms of chlorophyll content and yield.

The major share of soluble protein in leaves is contributed by the primary carbon dioxide assimilating enzyme ‘Rubisco’ and the soluble protein content is also a measure of photosynthetic efficiency. Like other photosynthetic promoting bimolecules, the soluble protein content was increased up to 120 DAS and decreased at 150 DAS. In the present investigation, the best identified treatment, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given on 50 and 75 DAS (T_9) significantly increased the soluble protein content at all growth stages (Fig. 8). The total soluble protein content also significantly and positively related to yield and the ‘r’ value was high (0.78) at 120 DAS (Table 32). The beneficial effect of supplementary nutrition of potassium and boron in improving soluble protein content and photosynthetic efficiency and yield was documented in several field crops. The importance of brassinolides spray on increasing the photochemical efficiency through rubisco activity and ultimate yield was established from the studies conducted in other field crops (Vardhini and Rao, 1998; Maibangasa *et al.,* 2000).

The enzymes, sucrose synthase and invertase play an important role in sugar metabolism of the plants. The sucrose synthase activity in leaves is important for sugar formation and accumulation of sugar content in tubers. The supplementary sprays of nutrients and plant growth regulator had stimulating effect on sucrose synthase activity, which ultimately results in higher level of sugars in leaves and root tubers. However, its activity decreased at 150 DAS and this may be due to the on set of senescence process during physiological maturity of root tuber (Fig. 9). The invertase activity in the root gradually decreased and reached very low activity at final stage of harvest. This may be due to accumulation of sucrose, a non reducing sugar in tubers (Fig. 10). The beneficial effect of potassium (Zehler *et al.,* 1981; Suyamto, 1998), boron (Gutieerrez, 1993; Kersten *et al.,* 1993) and Brassinolide (Braun and Wild., 1984) spray on sugar synthesis, transport and accumulation in sink organ is well documented from the studies conducted in several field crops.

The reducing sugar content in leaves and root of sugar beet at various phenophases revealed a positive improvement in photo assimilate production under the influence of nutrients and plant growth regulator. The reducing sugars gradually declined both in leaves and tubers with time trend due to conversion of reducing sugar to non reducing sugar and partitioning of sugars from leaves (source) to developing tubers (sink) and the reducing sugar content is negatively related to yield at final harvest stage. The total sugar content was high in leaves at the early stages and later the level sharply declined due to mobilization of sugars from leaves to tuber. This is evidenced from steady rise in total sugar levels in roots up to maturity (Fig. 11). The non reducing sugar, sucrose constitute the major share of total soluble solids in sugar beet and its tuber quality is basically decided by the TSS content at final harvest.. The TSS and non reducing sugar content gradually increased till the tubers reach the physiological maturity. The sugar accumulation and TSS content depends on the photo assimilate production and further its movements from the source leaves to sink tuber. The supplementary sprays of nutrients and plant growth regulator had stimulating effect on photo assimilate production and assimilate transport. In the present study combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS enhanced the non reducing sugar and TSS level at all growth stages and this was closely followed by combination spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS (Fig. 12). The non reducing sugars and total sugars of leaves and tuber are positively related to yield (Table 32). The studies conducted in many field crops by several workers revealed the crucial and positive role of foliar nutrition of potassium (Zehler *et al.*, 1981; Suyamto, 1998), boron (Porokhnevich, 1973; Gutieerrez, 1993; Kersten *et al.*, 1993; Wu and Wei, 1994; Brewbaker, 1998; Zhao Duli and Oosterhuis, 2000) and spray of synthetic steroid Brassinolide (Braun and Wild., 1984; Sala and Sala, 1985; Bellincampi and Morpurg, 1988; Maibangasa *et al.*, 2000) on photo assimilate production, transport and partitioning in favour of developing sink.

4.4. Yield and yield components

The sugar beet yield is decided by the individual root tuber size. The larger the tubers size higher the yield. The correlation coefficient studies of the root tuber characters with yield at different stages of the crop had significant positive effect. This was evident from the progressive increase of 'r' value with ontogeny of the crop (Table 33). The tuber length, girth and fresh weight progressively increased from root tuber initiation to physiological maturity in all the treatments. Although all the supplementary nutrients and plant growth regulator sprays are effective in improving tuber characteristics, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was found to be more effective in improving tuber dimensions and ultimately the sugar beet yield (Fig. 13). The next best identified treatment for high yield was the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS.

The partitioning of dry matter between storage organ and other non harvestable vegetative parts is very well expressed by the harvest index (HI). In many cases, economical yield was not always closely related with biological yield because of inefficient partitioning (Wallace, 1976). In the present study, potassium, boron and brassinolide combination sprays given at active growth phase brought out significant increase not only in total biomass production but also in partitioning of photo assimilates in favour of the tuber growth by registering high HI (Fig. 14). The yield increase due to better carbon assimilation and distribution in the best identified treatments accounted for 9.10 and 7.63 per cent respectively. The available literature is abundant regarding the beneficial effect of supplementary nutrition of potassium (Hallmark and Barber, 1981;

Sayed Mabdel Aal, 1990; Chakrabarty *et al*., 1993; Kapur, 1995; Johnston, 1997; Li Yu-ying and Liang Hong, 1997; Suyamto, 1998; Milford *et al.*, 2000; Ovidio Pérez and Mario Melgar, 2000) and boron (Hassanin and Abuldahab, 1991; Sasse, 1994; Schilling *et al.*, 1991; Thakur, *et al.*, 1991; Kawai *et al*., 1993; Singh and Dixit, 1994; Mahajan *et al.*, 1994; Barry *et al.*, 1995; Qosterhuis and Zhao, 2002) and foliar spray of Brassinolide(Diz *et al.*, 1990; Schilling *et al.*, 1991; Yokota *et al.*, 1992; Pirogovskaya *et al*., 1996; Vardhini and Rao, 1998) in improving yield and yield components through photosynthetic efficiency in biomass production and partitioning efficiency in terms of harvest index in several field crops.

The present study revealed the importance of the supplementary nutrients and plant growth regulator sprays on improving yield and net return. High net income of Rs. 18,019 ha^{-1} with a benefit: cost ratio of 1.50 was achieved by the combination spray of potassium 1 % and boron 0.5 % given twice on 50 and 75 DAS. The high benefit: cost ratio was realized due to low input cost and enhanced productivity. Although, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given on 50 and 75 DAS recorded higher yield, net income and benefit cost ratio was low due to high cost of brassinolide included in the combination spray.

CHAPTER VI

SUMMARY

The experimental results were critically analysed and discussed on the impact of foliar feeding of potassium, boron nutrients and brassinolide plant growth regulator to improve the growth, development, yield and quality of tropical sugar beet CV Indus. The results are summarized in this chapter.

5.1. Morphological traits

The plant height, leaf number and total leaf area of sugar beet increased with time trend and reached a static growth at 120 DAS and declined at harvest (150 DAS) due to senescence of lower leaves. The plant vigour in terms of leaf number, area and plant height was significantly increased by foliar spray of nutrients and plant growth regulator. The correlation co-efficient for plant vigour in terms of leaf number, area and plant height at different growth stages with yield revealed the importance of leaf area and leaf number on yield. The most effective treatment, KCl 1 % + boric acid 0.5 % + brassinolide 0.5 ppm spray given on 50 and 75 DAS recorded significantly higher values for the morphological characters of the plant. The next best identified treatment was the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS.

4.2. Growth analysis

Leaf area index was the maximum at tuber development stage and drastically declined at physiological maturity of the tuber due to senescence of leaves. Although all supplementary sprays of nutrients and plant growth regulator were beneficial in increasing LAI, the combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was identified as significantly superior treatment followed by the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS by recording the maximum values at all growth stages. The supplementary sprays of nutrients and plant growth regulator had beneficial effect through the delayed leaf senescence during tuber development stage by maintaining 10 to 11 per cent higher LAD than control.

The correlation coefficient values between SLW and final tuber yield was positive and highly significant during tuber development stage. Due to remobilization of photo assimilates from older leaves to the developing tuber, SLW showed an increasing trend in early stages and declined towards final harvest. As in LAI all the supplementary sprays of nutrients and plant growth regulator are found to be beneficial in increasing SLW. However, the combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was identified as significantly superior treatment to others. The next best identified treatment was the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS.

Sugar beet is basically a crop which accumulates predominantly the carbon compounds as total biomass. The supplementary sprays of nutrients and plant growth regulator had significant and profound effect on total dry matter production (TDMP) at all the stages. Although all the treatments had its share on increasing total dry matter production, the combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was identified as superior treatment followed by the next best treatment of combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS.

The supplementary sprays of nutrients and plant growth regulator had stimulating effect by recording higher CGR at all the growth stages particularly combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was identified as the most effective treatment, which recorded higher CGR values than control and other treatments. The relative growth rate also followed the same trend as that of CGR. However the RGR was drastically reduced towards harvest in all the treatments due to accumulation of more amount of photo assimilates in root tubers rather than in shoots.

The net assimilation rate, a measure of photosynthetic assimilation capacity of leaves was low in the beginning, increased at active growth phase and declined thereafter in all the treatments. The supplementary sprays of nutrients and plant growth regulator had stimulating effect on assimilation potential of leaves by recording higher NAR at all the growth stages, particularly combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was the most efficient treatment, which recorded higher NAR values than control and other treatments.

The growth rates, CGR, RGR and NAR were significantly and positively related to yield at all the growth stages. It is evident that the tuber yield was greatly depending on growth rates in terms of dry matter accumulation per unit leaf area and per unit land area. All the supplementary sprays of nutrients and plant growth regulator had stimulating effect on growth rates which in turn reflected on increased yield over control. The sugar beet crop is positively responding to supplementary nutrients and its growth is stimulated by plant growth regulator.

4.3. Physiological and biochemical traits

The nutrients and plant growth regulator positively enhanced photosynthetic pigments *viz.* chlorophyll 'a' and chlorophyll 'b'. The pigments concentration increased gradually and reached the maximum at 120 DAS and decreased at 150 DAS due to senescence process. Combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given on 50 and 75 DAS not only recorded highest chlorophyll content at 90 and 120 DAS but also maintained higher level at 150 DAS with less reduction, when other treatments showed more reduction at final stage of growth.

The soluble protein content was increased up to 120 DAS and decreased at 150 DAS. In the present investigation, the best identified treatment, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given on 50 and 75 DAS (T_9) significantly increased the soluble protein content at all growth stages. The total soluble protein content significantly and positively related to yield.

The sucrose synthase activity in leaves is important for sugar formation and accumulating the sugar content in tubers. The supplementary sprays of nutrients and plant growth regulator had stimulating effect on sucrose synthase activity, which ultimately results in higher level of sugars in leaves and root tubers. However, its activity decreased at 150 DAS and this may be due to on set of senescence process during physiological maturity of root tuber. The Invertase activity in the root gradually decreased and reached very low activity at final harvest due to accumulation of sucrose, a non reducing sugar in tubers.

The reducing sugars gradually declined both in leaves and tubers with time trend due to conversion of reducing sugar to non reducing sugar and partitioning of sugars from source leaves to sink tuber. The total sugar content was high in leaves at the early stages and later on the level sharply declined due to mobilization of sugars from leaves to tuber. The non reducing sugar, sucrose constitutes the major share of total soluble solids in sugar beet and its tuber quality is basically decided by the TSS content at final harvest. The TSS and non reducing sugar content gradually increased till the tubers reach the physiological maturity. The supplementary sprays of nutrients and plant growth regulator had stimulating effect on photo assimilate production and assimilate transport. In the present study combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS enhanced the non reducing sugar and TSS level at all growth stages and this was closely followed by combination spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS.

4.4. Yield and yield components

The sugar beet yield is decided by the individual root tuber size. The correlation coefficient studies of the root tuber characters with yield at different stages of the crop had significant positive effect. Although all the supplementary nutrients and plant growth regulators sprays are effective in improving tuber characteristics, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS was found to be more effective in improving tuber dimensions and ultimately the sugar beet yield. The next best identified treatment was the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS.

The partitioning of dry matter between storage organ and other non harvestable vegetative part is very well expressed by the harvest index (HI). In the present study, potassium, boron and brassinolide combination sprays given at active growth phase brought out significant increase not only in total biomass production but also in partitioning of photo assimilates in favour of the tuber growth by registering high HI.

The present study revealed the importance of the supplementary nutrients and plant growth regulators sprays on improving yield and net return. High net income of Rs. 18,019 ha^{-1} with a benefit: cost ratio of 1.50 was achieved by the combination spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS. The high benefit: cost ratio was realized due to low input cost and enhanced productivity. Although, combination spray of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given on 50 and 75 DAS recorded higher yield, net income and benefit cost ratio was low due to high cost of brassinolide included in the combination spray.

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Research findings

Impact of foliar spray of potassium, boron and brassinolide in improving assimilate partitioning in tropical sugar beet

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Studies were conducted to understand the impact of foliar feeding of potassium and boron nutrients and brassinolide, a plant growth regulator to improve the growth, development, yield and quality of tropical sugar beet CV. Indus. The treatments include foliar spray of potassium chloride 1 %, boric acid 0.5 % and brassinolide 0.5 ppm either individually or in combination given as a single spray at 50 DAS or as double spray at 50 and 75 DAS.

Among the foliar spray treatments, the combination spray of KCl 1 % + boric acid 0.5 % + brassinolide 0.5 ppm given twice on 50 and 75 DAS was identified as the most effective treatment which was followed by the combined nutrient spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS in increasing plant vigour in terms of leaf number, leaf area and plant height which reached a peak at120 DAS and declined at harvest due to senescence of lower leaves; also had its positive influence on other growth parameters *viz.* SLW, RGR, NAR CGR, and total dry matter production. All these growth parameters were positively related to yield.

The combination spray of KCl 1 % + boric acid 0.5 % + brassinolide 0.5 ppm given twice on 50 and 75 DAS followed by KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS enhanced photosynthetic pigments, soluble protein content and sucrose synthase activity in leaves results in increased levels of TSS and sugars in tubers thereby improved the tuber characteristics, HI and sugar beet yield. High net income of Rs.

18,019 ha^{-1} with a benefit: cost ratio of 1.50 was achieved by the combination spray of KCl 1 % and boric acid 0.5 % given twice on 50 and 75 DAS. Although, combination sprays of KCl 1 %, boric acid 0.5 % and brassinolide 0.5 ppm given twice on 50 and 75 DAS recorded higher yield, net income and the benefit cost ratio was low due to high cost of brassinolide included in the combination spray.

Table 3 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on plant height (cm)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	24.1	36.0	37.7	31.9
T_2	24.3	37.0	39.3	32.3
T_3	24.3	38.2	40.1	33.3
T_4	26.3	37.5	39.0	32.5
T_5	26.1	38.4	40.3	33.1
T_6	27.1	37.4	38.7	32.1
T_7	24.3	38.1	41.3	33.4
T_8	25.9	38.9	40.5	33.7
T_9	27.5	40.9	42.1	35.3
T_{10}	25.8	39.9	40.8	33.9
Mean	25.2	38.2	39.9	33.2
SEd	0.05	0.05	0.06	0.07
CD (0.05)	0.10	0.11	0.13	0.15

Table 4 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on leaf number plant^{-1}

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	18.0	23.7	24.2	11.8
T_2	18.4	24.5	25.1	12.5
T_3	18.5	25.3	25.8	13.1
T_4	19.2	24.3	25.0	12.2
T_5	18.5	25.5	25.8	12.7
T_6	18.3	24.3	24.9	12.5
T_7	18.6	25.0	25.5	13.0
T_8	19.1	25.8	26.2	13.5
T_9	19.6	26.1	27.1	13.7
T_{10}	19.4	25.9	26.3	13.5
Mean	18.2	25.0	25.6	12.9
SEd	0.03	0.02	0.24	0.07
CD (0.05)	0.06	0.05	0.50	0.16

Table 5 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on leaf area (cm^2 $plant^{-1}$)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	4351.7	5188.1	5525.6	1033.2
T_2	4377.5	5385.4	5624.4	1104.4
T_3	4420.2	5578.9	5825.5	1111.1
T_4	4371.8	5378.1	5673.4	1105.3
T_5	4458.1	5602.9	5928.6	1144.6
T_6	4376.4	5359.3	5671.9	1119.1
T_7	4416.9	5570.3	5866.6	1154.8
T_8	4460.5	5683.5	6009.1	1166.6
T_9	4560.6	5834.4	6130.9	1361.0
T_{10}	4543.8	5747.0	6042.5	1244.7
Mean	4438.6	5532.8	5829.9	1154.9
SEd	1.82	5.07	5.09	5.29
CD (0.05)	3.81	10.65	10.66	4.80

Table 6 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on leaf area index

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	4.29	5.19	6.02	0.66
T_2	4.38	5.29	6.11	0.70
T_3	4.45	5.53	6.29	0.73
T_4	4.30	5.30	6.17	0.70
T_5	4.34	5.54	6.27	0.72
T_6	4.37	5.34	6.21	0.69
T_7	4.42	5.38	6.22	0.71
T_8	4.65	5.65	6.38	0.74
T_9	4.83	5.95	6.46	0.80
T_{10}	4.75	5.68	6.41	0.78
Mean	4.56	5.5	6.23	0.74
SEd	0.052	0.073	0.060	0.046
CD (0.05)	0.109	0.153	0.123	0.097

Table 7 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on specific leaf weight (mg cm^{-2})

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	4.44	7.04	8.21	5.20
T_2	4.87	7.24	8.61	5.23
T_3	4.75	7.54	8.68	5.24
T_4	4.81	7.54	8.56	5.24
T_5	4.68	7.44	8.61	5.26
T_6	4.64	7.05	8.42	5.25
T_7	4.57	7.39	8.61	5.30
T_8	4.75	7.55	8.73	5.97
T_9	4.98	7.85	9.09	6.33
T_{10}	4.96	7.59	8.80	6.15
Mean	4.73	7.42	8.64	5.51
SEd	0.022	0.041	0.035	0.066
CD (0.05)	0.046	0.086	0.073	0.136

Table 8 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on leaf area duration

Treatments	60 – 90 DAS	90 – 120 DAS	120 – 150 DAS
T_1	146.2	168.1	100.2
T_2	148.4	174.9	103.1
T_3	149.7	180.0	106.1
T_4	148.9	173.2	103.3
T_5	152.1	180.8	107.4
T_6	150.4	177.2	103.4
T_7	151.6	177.9	105.5
T_8	154.5	183.0	109.2
T_9	158.8	186.2	112.8
T_{10}	155.3	185.4	111.1
Mean	151.6	178.7	106.2
SEd	0.09	0.15	0.10
CD (0.05)	0.19	0.32	0.22

Table 9 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on total dry matter production (g $plant^{-1}$)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	30.2	70.5	121.1	150.3
T_2	31.4	74.3	126.8	158.2
T_3	32.0	75.4	130.6	162.2
T_4	31.3	74.8	128.9	157.8
T_5	32.0	76.0	131.0	163.4
T_6	31.2	74.6	125.7	156.2
T_7	31.6	75.2	130.0	162.0
T_8	32.3	76.2	135.7	164.0
T_9	33.7	80.5	137.4	171.0
T_{10}	33.1	78.3	134.6	166.3
Mean	31.8	73.0	130.2	161.1
SEd	0.07	11.38	0.14	0.15
CD (0.05)	0.15	23.91	0.28	0.32

Table 10 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on crop growth rate (g m^{-2} day^{-1})

Treatments	60 – 90 DAS	90 – 120 DAS	120 – 150 DAS
T_1	13.42	16.58	9.37
T_2	14.31	17.17	9.57
T_3	14.41	17.76	10.16
T_4	14.50	17.07	9.37
T_5	14.60	17.86	10.06
T_6	14.50	16.87	9.77
T_7	14.31	17.46	9.87
T_8	14.80	18.06	10.46
T_9	15.59	19.34	11.05
T_{10}	15.00	18.65	10.66
Mean	14.54	17.70	10.11
SEd	0.015	0.061	0.045
CD (0.05)	0.031	0.129	0.094

Table 11 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on relative growth rate (mg g^{-1} day^{-1})

Treatments	60 – 90 DAS	90 – 120 DAS	120 – 150 DAS
T_1	77.9	138.4	41.6
T_2	81.1	141.5	43.8
T_3	79.1	144.8	45.7
T_4	81.2	141.7	44.8
T_5	87.4	144.9	45.9
T_6	86.3	141.7	43.0
T_7	82.3	143.4	49.4
T_8	83.7	146.9	47.1
T_9	88.1	153.2	48.6
T_{10}	84.1	148.5	47.4
Mean	83.1	144.5	45.7
SEd	0.09	0.14	0.93
CD (0.05)	0.19	0.30	0.20

Table 12 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on net assimilation rate (mg cm^{-2} day^{-1})

Treatments	60 – 90 DAS	90 – 120 DAS	120 – 150 DAS
T_1	0.12	0.43	0.23
T_2	0.14	0.46	0.25
T_3	0.15	0.48	0.27
T_4	0.14	0.45	0.24
T_5	0.16	0.49	0.28
T_6	0.15	0.46	0.24
T_7	0.17	0.44	0.29
T_8	0.17	0.50	0.29
T_9	0.22	0.53	0.35
T_{10}	0.20	0.51	0.31
Mean	0.15	0.47	0.26
SEd	0.030	0.078	0.041
CD (0.05)	0.063	0.167	0.081

Table 13 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on Chlorophyll ' a' content (mg g^{-1} fw)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	0.780	1.166	1.557	0.630
T_2	0.786	1.265	1.575	0.635
T_3	0.795	1.273	1.584	0.643
T_4	0.784	1.224	1.571	0.636
T_5	0.805	1.269	1.580	0.640
T_6	0.790	1.239	1.565	0.636
T_7	0.803	1.267	1.584	0.639
T_8	0.808	1.301	1.611	0.653
T_9	0.814	1.308	1.621	0.659
T_{10}	0.810	1.302	1.617	0.655
Mean	0.830	1.213	1.593	0.643
SEd	0.031	0.223	0.053	0.045
CD (0.05)	0.065	0.466	0.111	0.094

Table 14 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on Chlorophyll ' b' content (mg g^{-1} fw)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	0.212	0.351	0.728	0.173
T_2	0.217	0.363	0.738	0.166
T_3	0.221	0.365	0.731	0.176
T_4	0.219	0.360	0.737	0.180
T_5	0.224	0.375	0.752	0.179
T_6	0.220	0.357	0.749	0.170
T_7	0.223	0.346	0.751	0.175
T_8	0.229	0.395	0.753	0.182
T_9	0.232	0.403	0.766	0.191
T_{10}	0.230	0.398	0.761	0.186
Mean	0.19	0.367	0.74	0.193
SEd	0.045	0.062	0.031	0.029
CD (0.05)	0.094	0.13	0.063	0.062

Table 15 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on total Chlorophyll content (mg g^{-1} fw)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	1.162	1.632	2.265	0.820
T_2	1.166	1.655	2.311	0.844
T_3	1.166	1.669	2.338	0.849
T_4	1.165	1.647	2.329	0.839
T_5	1.168	1.677	2.337	0.852
T_6	1.167	1.664	2.320	0.833
T_7	1.165	1.665	2.290	0.851
T_8	1.173	1.703	2.360	0.858
T_9	1.178	1.708	2.374	0.870
T_{10}	1.175	1.704	2.366	0.865
Mean	1.157	1.683	2.320	0.837
SEd	0.045	0.04	0.094	0.015
CD (0.05)	0.094	0.094	0.198	0.031

Table 16 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on soluble protein content (mg g^{-1} fw)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	7.99	9.72	12.83	6.04
T_2	8.09	10.11	14.15	6.26
T_3	8.44	10.75	14.29	6.31
T_4	8.31	10.31	13.50	6.35
T_5	8.39	10.61	14.26	6.48
T_6	8.25	10.20	13.71	6.20
T_7	8.40	10.56	14.26	6.43
T_8	8.61	10.85	14.50	6.63
T_9	8.98	12.14	15.05	6.91
T_{10}	8.74	11.45	14.60	6.71
Mean	8.44	10.68	14.12	6.45
SEd	0.061	0.065	0.033	0.070
CD (0.05)	0.127	0.137	0.069	0.147

Table 17 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on sucrose synthase activity in leaf (μmol g^{-1} fw h^{-1})

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	11.42	16.87	21.51	7.10
T_2	12.09	16.36	22.95	8.11
T_3	12.27	17.31	23.53	8.14
T_4	12.20	16.06	23.06	8.25
T_5	12.30	17.45	23.33	8.08
T_6	12.07	15.98	22.86	8.26
T_7	11.94	16.72	23.20	7.90
T_8	12.38	17.96	23.63	8.34
T_9	13.03	19.06	24.45	9.72
T_{10}	12.53	18.36	23.82	8.87
Mean	12.23	17.20	23.24	8.29
SEd	0.063	0.063	0.039	0.079
CD (0.05)	0.132	0.133	0.083	0.165

Table 18 Effect of nutrients (Potassium and Boron) and plant growth regulators (Brassinolide) on invertase activity in root (μmol g^{-1} fw h^{-1})

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	12.83	7.65	2.07	0.17
T_2	13.75	7.63	2.26	0.18
T_3	14.02	8.76	2.29	0.18
T_4	13.07	8.29	2.19	0.18
T_5	14.16	9.17	2.32	0.18
T_6	13.27	8.11	2.32	0.18
T_7	13.45	8.55	2.27	0.18
T_8	14.54	10.05	2.30	0.18
T_9	15.60	10.85	2.20	0.19
T_{10}	14.81	10.44	2.36	0.19
Mean	13.97	9.46	2.26	0.19
SEd	0.073	0.047	NS	NS
CD (0.05)	0.153	0.099	-	-

Table 19 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on reducing sugars in leaf (mg g^{-1} fw)

Treatments	90 DAS	120 DAS	150 DAS
T_1	4.39	1.94	1.00
T_2	4.65	2.12	1.15
T_3	4.76	2.15	1.26
T_4	4.61	2.03	1.12
T_5	4.84	2.17	1.28
T_6	4.60	2.10	1.08
T_7	4.70	2.12	1.19
T_8	4.91	2.14	1.33
T_9	5.19	2.26	1.45
T_{10}	5.09	2.19	1.36
Mean	4.86	2.12	1.13
SEd	0.050	0.024	0.041
CD (0.05)	0.105	0.051	0.087

Table 20 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on reducing sugars in root (mg g^{-1} fw)

Treatments	90 DAS	120 DAS	150 DAS
T_1	4.38	1.12	0.41
T_2	4.68	1.31	0.45
T_3	4.85	1.56	0.47
T_4	4.60	1.38	0.53
T_5	4.96	1.59	0.48
T_6	4.66	1.47	0.44
T_7	4.72	1.48	0.47
T_8	4.88	1.69	0.49
T_9	5.17	1.86	0.53
T_{10}	5.07	1.74	0.50
Mean	4.85	1.50	0.40
SEd	0.046	0.070	NS
CD (0.05)	0.097	0.147	-

Table 21 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on total sugars in leaf (mg g^{-1} fw)

Treatments	90 DAS	120 DAS	150 DAS
T_1	16.83	9.10	3.94
T_2	17.37	9.30	4.10
T_3	17..21	9.59	4.50
T_4	17.21	9.38	4.37
T_5	17.69	9.67	4.51
T_6	17.09	9.16	4.05
T_7	17.48	9.4.9	4.41
T_8	17.83	9.79	4.52
T_9	18.16	10.00	4.78
T_{10}	18.00	9.96	4.60
Mean	17.51	9.53	4.38
SEd	0.077	0.053	0.057
CD (0.05)	0.161	0.111	0.120

Table 22 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on total sugars in root (mg g^{-1} fw)

Treatments	90 DAS	120 DAS	150 DAS
T_1	24.56	72.68	129.75
T_2	24.93	73.21	132.47
T_3	25.50	74.09	135.96
T_4	25.02	73.39	133.13
T_5	25.56	73.93	136.22
T_6	24.95	72.86	132.83
T_7	25.35	73.70	134.86
T_8	25.87	74.37	136.74
T_9	25.97	74.94	138.61
T_{10}	25.98	74.93	137.24
Mean	25.35	73.78	134.89
SEd	0.082	0.079	0.174
CD (0.05)	0.168	0.166	0.365

Table 23. Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolides) on non reducing sugars in leaf (mg g^{-1} fw)

Treatments	90 DAS	120 DAS	150 DAS
T_1	16.91	9.19	4.01
T_2	16.99	9.30	4.19
T_3	17.53	9.55	4.31
T_4	17.11	9.60	4.25
T_5	17.55	9.37	4.26
T_6	17.16	9.20	4.22
T_7	17.25	9.53	4.30
T_8	17.63	9.68	4.40
T_9	17.98	9.90	4.73
T_{10}	17.79	9.79	4.48
Mean	17.38	9.50	4.31
SEd	0.063	0.050	0.087
CD (0.05)	0.133	0.105	0.182

Table 24. Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolides) on non reducing sugars in root (mg g^{-1} fw)

Treatments	90 DAS	120 DAS	150 DAS
T_1	20.18	71.56	129.34
T_2	20.25	71.90	132.02
T_3	20.65	72.53	135.49
T_4	20.42	72.01	132.60
T_5	20.60	72.34	135.74
T_6	20.29	71.39	132.39
T_7	20.63	72.22	134.39
T_8	20.99	72.68	136.25
T_9	20.80	73.08	138.08
T_{10}	20.91	73.19	136.74
Mean	20.50	72.28	134.49
SEd	0.071	0.089	0.356
CD (0.05)	0.150	0.186	0.748

Table 25 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on TSS (° brix)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	1.0	4.0	7.9	14.6
T_2	1.3	4.4	9.1	14.8
T_3	1.2	4.6	9.4	15.4
T_4	1.9	4.3	9.5	15.0
T_5	1.9	4.5	9.8	15.3
T_6	1.6	4.2	9.3	15.3
T_7	1.1	3.7	9.5	15.2
T_8	1.7	4.9	9.1	15.8
T_9	1.8	5.5	10.4	16.7
T_{10}	1.4	5.0	10.0	16.1
Mean	1.5	4.5	9.4	15.4
SEd	0.03	0.05	0.03	0.08
CD (0.05)	0.06	0.09	0.07	0.16

Table 26 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on tuber length (cm)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	19.5	21.4	25.6	28.7
T_2	19.7	21.9	26.2	29.8
T_3	20.1	23.2	27.0	30.5
T_4	19.9	22.6	25.9	30.0
T_5	20.3	23.1	26.8	30.6
T_6	20.0	22.7	26.4	29.7
T_7	20.4	23.0	27.2	30.4
T_8	20.7	23.5	28.0	31.0
T_9	21.9	24.9	29.3	32.8
T_{10}	20.8	23.9	28.6	31.4
Mean	20.3	22.9	27.3	30.5
SEd	0.06	0.07	0.05	0.03
CD (0.05)	0.13	0.15	0.11	0.07

Table 27 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on tuber girth (cm)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	20.9	27.0	30.8	36.1
T_2	21.6	28.2	32.0	36.6
T_3	22.0	29.5	33.2	36.9
T_4	22.2	28.4	31.9	36.5
T_5	21.6	29.9	33.0	37.3
T_6	21.0	27.6	31.5	37.0
T_7	21.2	29.7	32.6	36.4
T_8	21.7	30.4	33.5	38.6
T_9	22.4	31.4	34.7	39.7
T_{10}	22.0	31.0	34.1	39.0
Mean	21.6	29.3	32.7	37.4
SEd	0.03	0.07	0.05	0.05
CD (0.05)	0.07	0.15	0.10	0.11

Table 28 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on tuber fresh weight (g $plant^{-1}$)

Treatments	60 DAS	90 DAS	120 DAS	150 DAS
T_1	301.1	562.6	701.0	955.8
T_2	385.2	537.2	710.9	972.3
T_3	346.0	585.8	770.0	986.7
T_4	306.2	553.3	789.3	960.7
T_5	311.5	534.2	799.2	1011.3
T_6	296.0	585.8	780.1	977.6
T_7	317.3	505.7	797.4	1045.9
T_8	312.4	604.2	803.8	1060.7
T_9	383.2	668.2	868.3	1124.8
T_{10}	321.1	618.0	823.9	1085.3
Mean	328.0	575.5	784.4	1018.1
SEd	0.81	1.19	1.25	1.48
CD (0.05)	1.70	2.50	2.62	3.10

Table 29 Effect of nutrients (Potassium and Boron) and plant growth regulator (Brassinolide) on moisture content (%), yield (t ha^{-1}) and harvest index (%)

Treatments	Moisture content	Yield	Harvest index
T_1	83.0	59.78	66.55
T_2	83.0	60.63	66.82
T_3	82.9	63.40	69.18
T_4	83.0	60.21	67.36
T_5	83.4	63.23	69.57
T_6	83.6	60.84	68.00
T_7	83.0	64.16	68.29
T_8	83.7	64.16	69.87
T_9	83.1	65.22	71.94
T_{10}	83.5	64.34	70.88
Mean	83.2	62.39	68.79
SEd	NS	0.057	0.044
CD (0.05)	NS	0.120	0.093

Table 31 Correlation Co-efficient of morphological and growth attributes with yield

	Correlation Co- efficient (‘ r ‘values)			
	60 DAS	90 DAS	120 DAS	150 DAS
Plant Height	0.46	0.79	0.81	0.71
Leaf number	0.57	0.64	0.74	0.71
Leaf area	0.76	0.77	0.79	0.76
LAI	0.62	0.64	0.70	0.65
SLW	0.31	0.65	0.76	0.71
TDMP	0.78	0.75	0.80	0.84
	60 – 90 DAS	90-120 DAS	120 – 150 DAS	
LAD	0.74	0.76	0.78	
CGR	0.62	0.70	0.74	
RGR	0.66	0.74	0.75	
NAR	0.65	0.68	0.72	

Table 32 Correlation Co-efficient of physiological and biochemical traits with yield

	Correlation Co- efficient (‘ r ‘values)			
	60 DAS	90 DAS	120 DAS	150 DAS
Chlorophyll “a”	0.62	0.70	0.74	0.71
Chlorophyll “b”	0.63	0.71	0.72	0.76
Total Chlorophyll	0.55	0.62	0.70	0.65
Soluble protein	0.75	0.77	0.78	0.71
Sucrose synthase	0.64	0.75	0.81	0.74
Total sugars (Leaf)	-	0.77	0.71	0.69
Total sugars (Root)	-	0.75	0.76	0.73
Non-reducing sugar (Leaf)	-	0.67	0.60	0.59
Non-reducing sugar (Root)	-	0.70	0.74	0.76
Reducing sugar (Leaf)	-	0.70	0.69	- 0.44
Reducing sugar (Root)	-	0.70	0.64	- 0.48

Table 33 Correlation Co-efficient of yield and yield component at different stages

Characters	Correlation Co- efficient (‘ r ‘values)			
	60 DAS	90 DAS	120 DAS	150 DAS
Tuber length	0.71	0.73	0.76	0.77
Tuber girth	0.65	0.70	0.74	0.76
Tuber weight	0.56	0.67	0.70	0.74
Harvest index				0.78
Moisture content				0.66

Table 30 Benefit: cost ratio in sugar beet production under different treatments

Treatments	Expenditure excluding treatmental cost (Rs.)	cost of Treatment (Rs.)	Total cost of cultivation (Rs.)	Tuber yield t ha^{-1}	Tuber income @ Rs. 800 t^{-1}	Biomass income @ Rs. 250 t^{-1}	Total gross income (Rs.)	Net income (Rs.)	Benefit: cost ratio
T_1	34,000	-	34,000	59.78	47,824	1,496	49,320	15,320	1.45
T_2	34,000	250	34,250	60.63	48,504	1,533	50,037	15,787	1.46
T_3	34,000	500	34,500	63.40	50,820	1,585	52,225	17,725	1.51
T_4	34,000	305	34,305	60.21	48,168	1,505	49,673	15,368	1.45
T_5	34,000	610	34,610	63.23	50,584	1,580	52,164	15,554	1.52
T_6	34,000	1095	35,095	60.84	48,672	1,535	50,207	15,112	1.43
T_7	34,000	2190	36,190	64.16	51,328	1,605	52,933	16,743	1.46
T_8	34,000	1200	35,200	64.16	51,328	1,605	52,933	17,733	1.50
T_9	34,000	2400	36,400	65.22	52,176	1,630	53,806	17,406	1.48
T_{10}	34,000	660	35,060	64.34	51,472	1,607	53,079	18,019	1.51

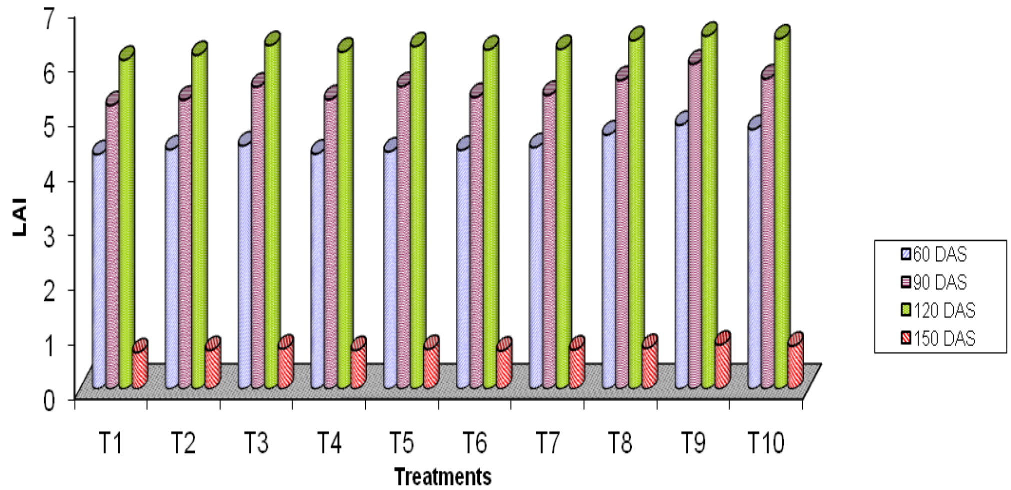

Fig. 2 Effects of Nutrients and Plant growth regulator on Leaf Area Index (LAI)

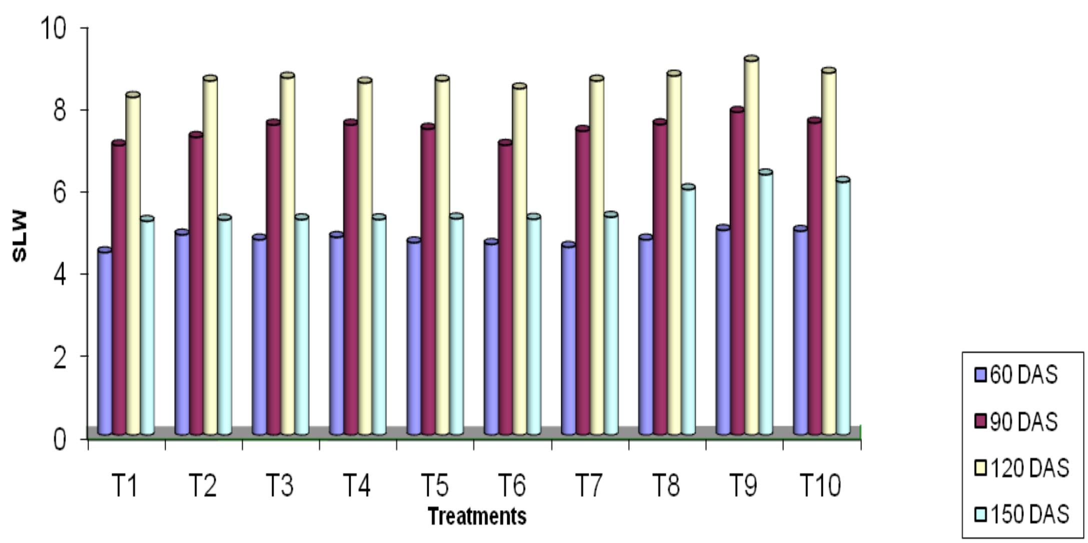

Fig. 3 Effects of Nutrients and Plant growth regulator on Specific Leaf Weight (mg cm-2)

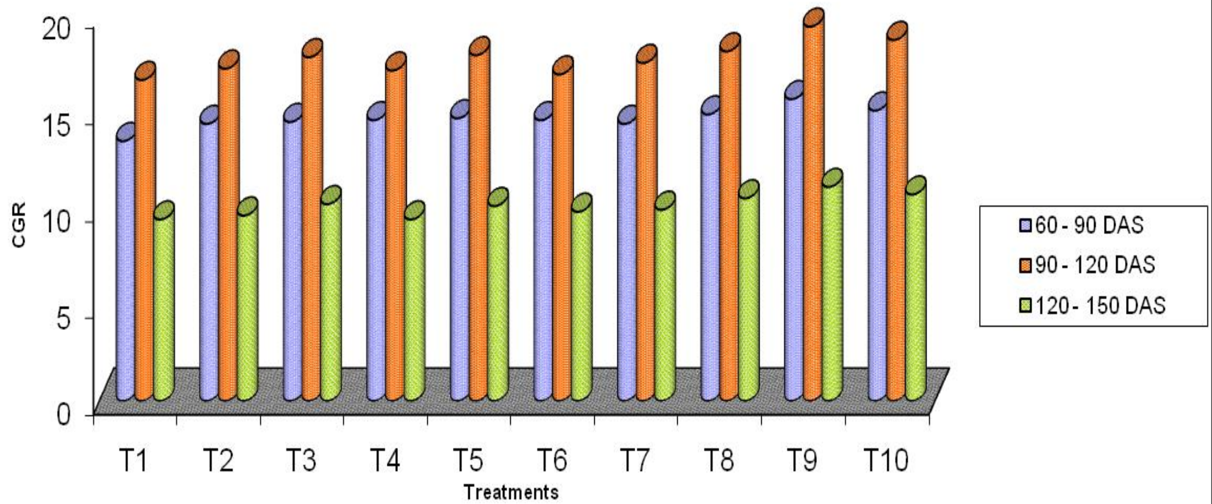

Fig.4 Effects of Nutrients and Plant growth regulator on Crop Growth Rate (CGR) (g m-2 day-1)

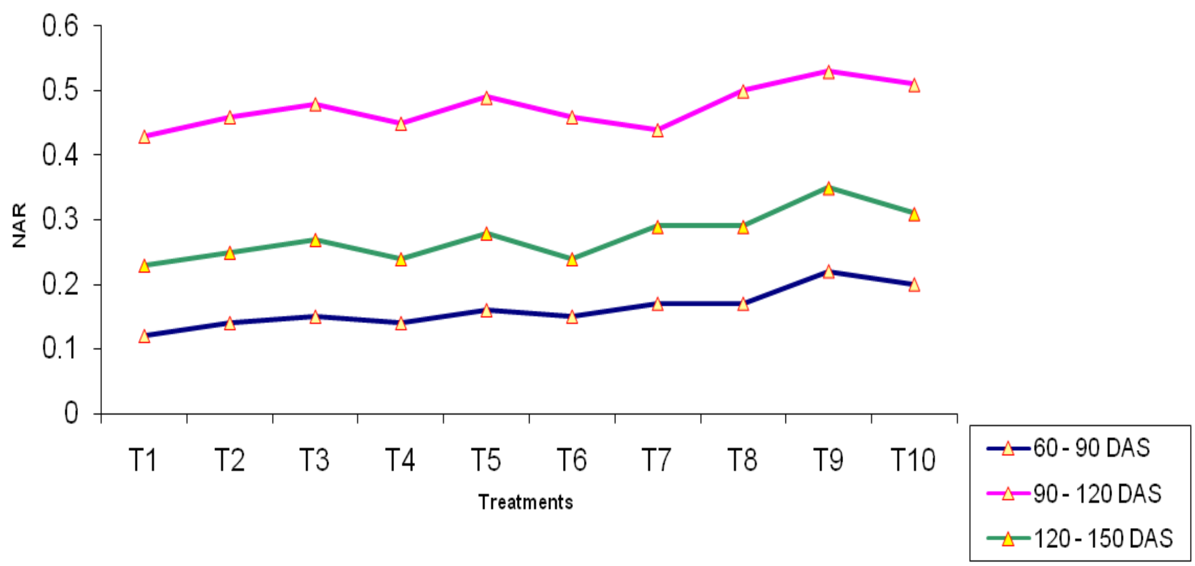

Fig.5 Effects of Nutrients and Plant growth regulator on Net Assimilation Rate (NAR) (mg cm-2 day-1)

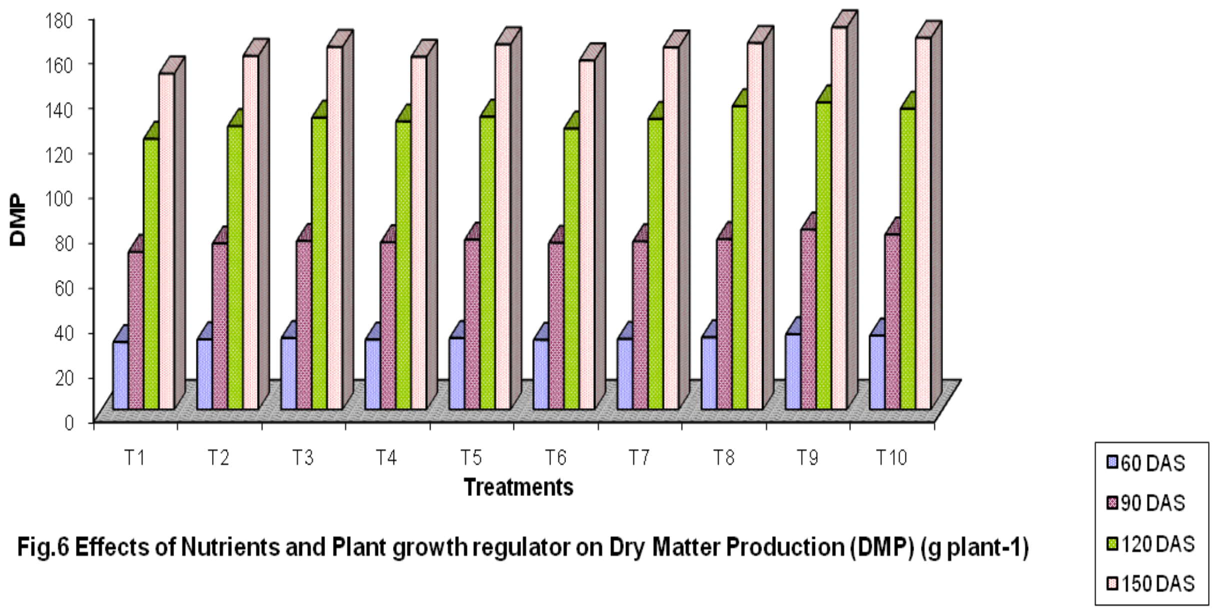

Fig.6 Effects of Nutrients and Plant growth regulator on Dry Matter Production (DMP) (g plant-1)

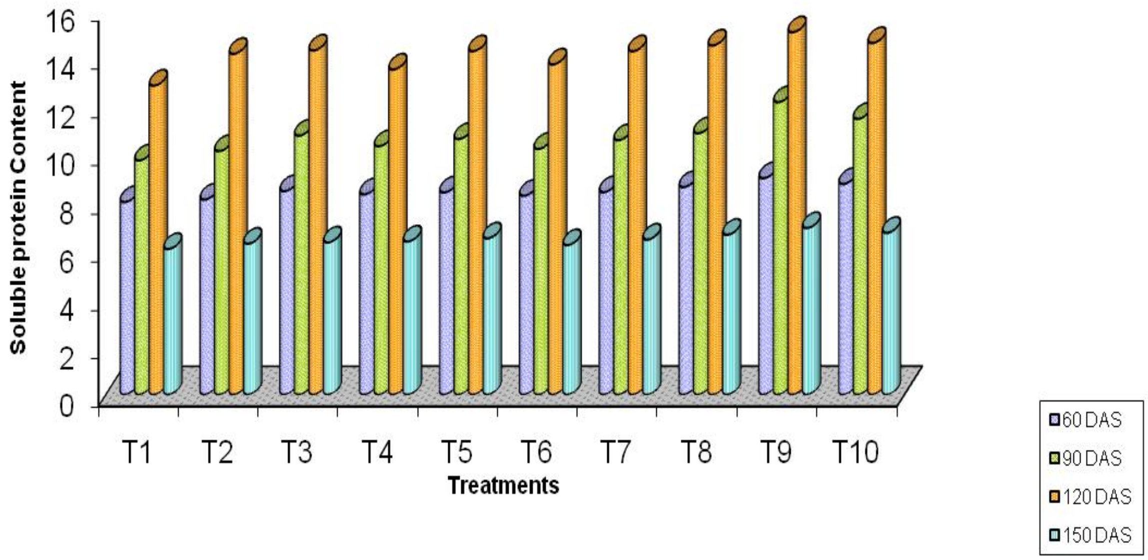

Fig.7 Effects of Nutrients and Plant growth regulator onSoluble protein Content (mg g-1 fw)

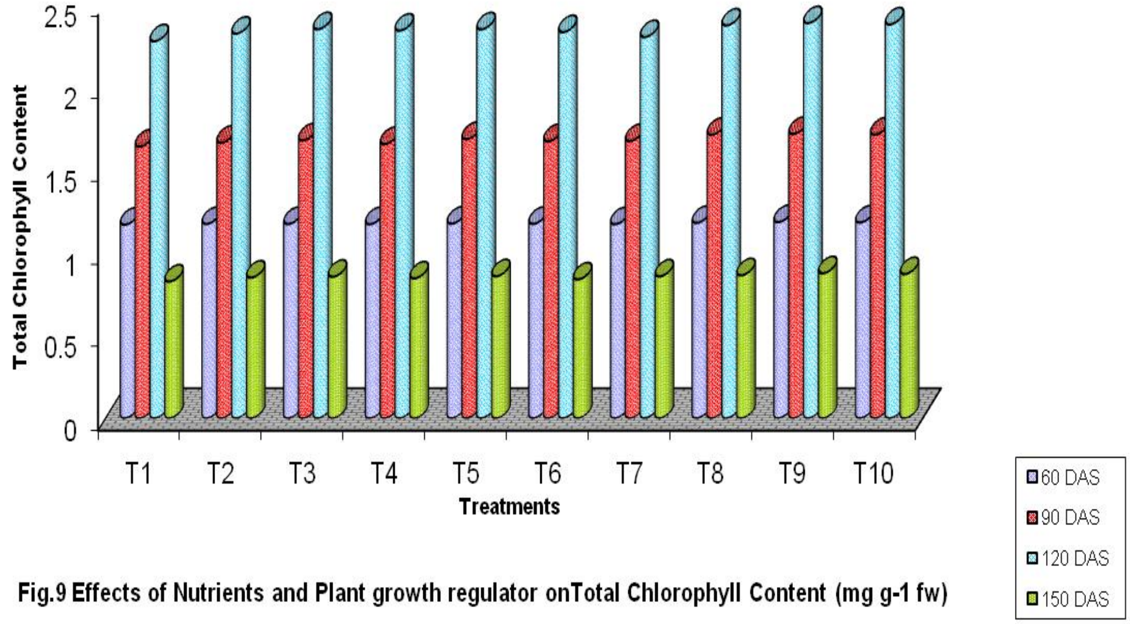

Fig.9 Effects of Nutrients and Plant growth regulator onTotal Chlorophyll Content (mg g-1 fw)

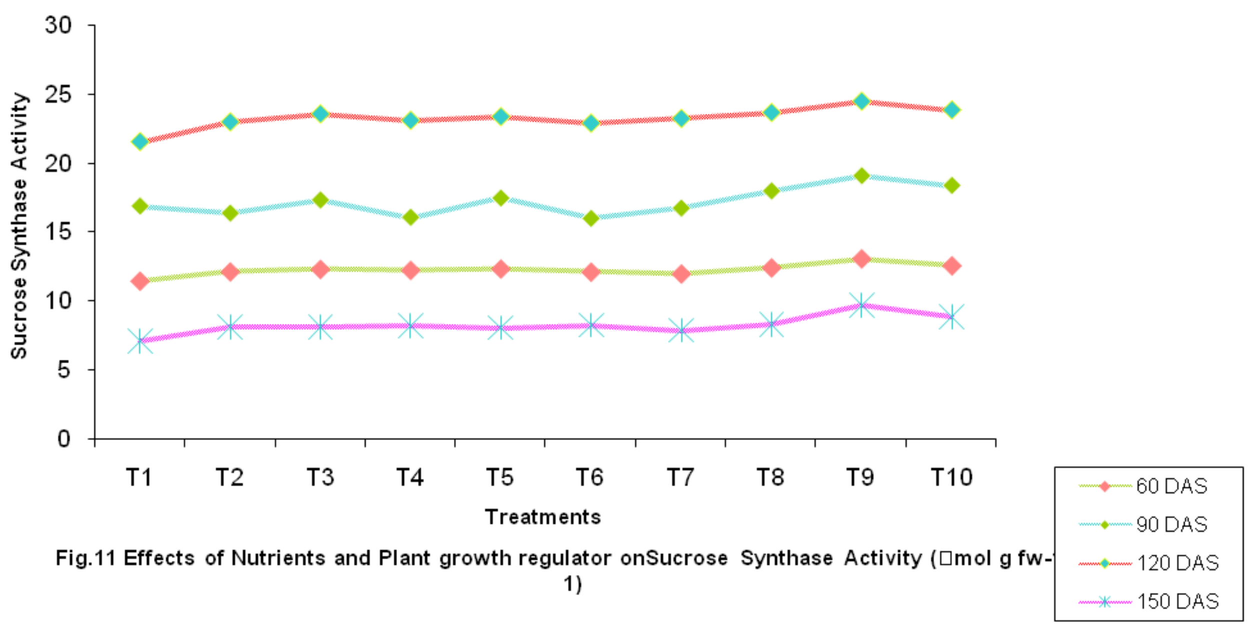

Fig.11 Effects of Nutrients and Plant growth regulator onSucrose Synthase Activity (□mol g fw-1)

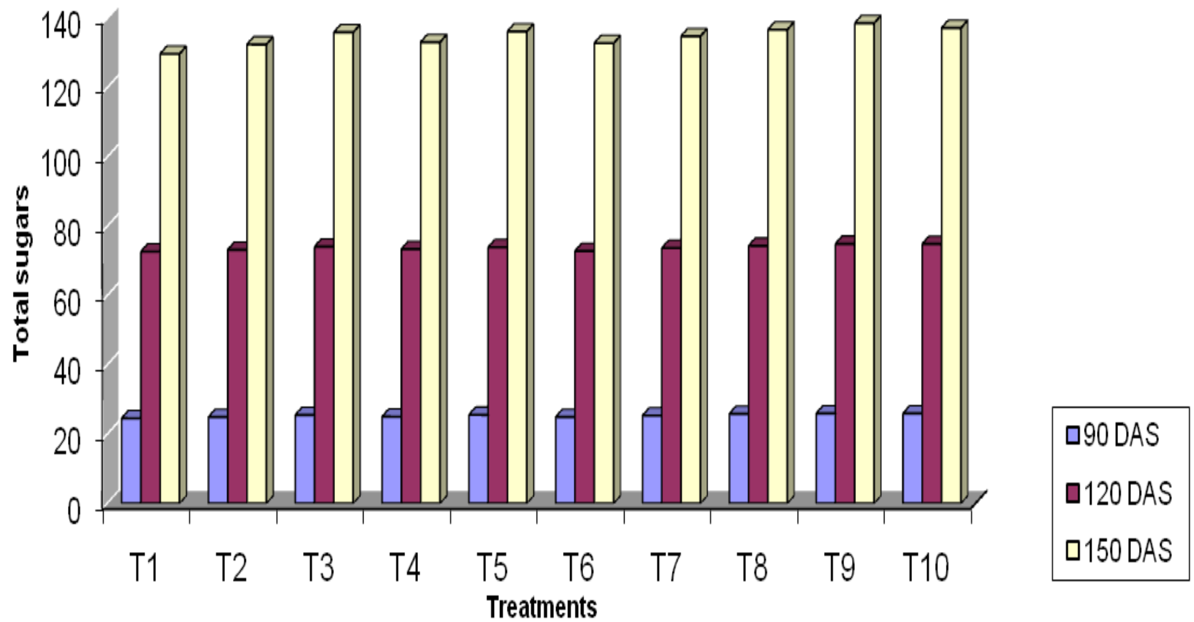

Fig.13 Effects of Nutrients and Plant growth regulator onTotal sugrs in Roots (mg g-1 fw)

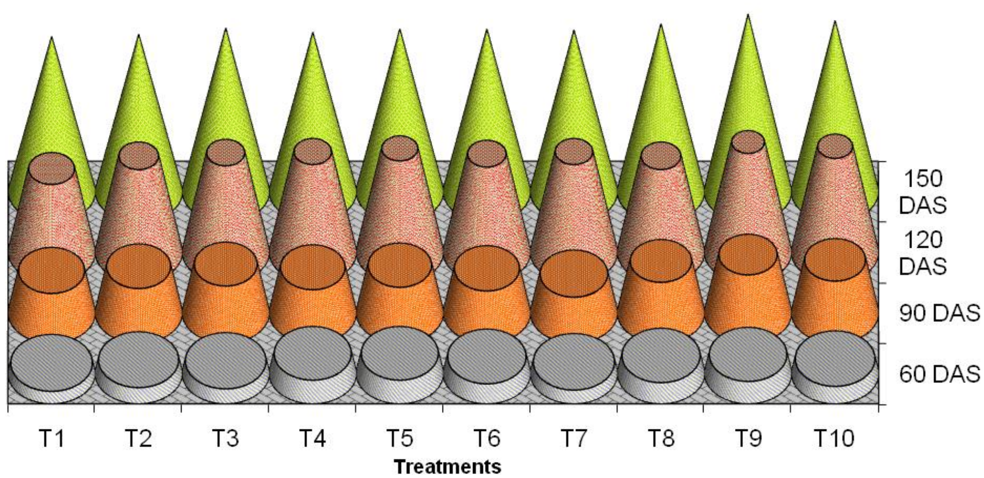

Fig.10 Effects of Nutrients and Plant growth regulator Total Soluble Solids (TSS) (° brix)

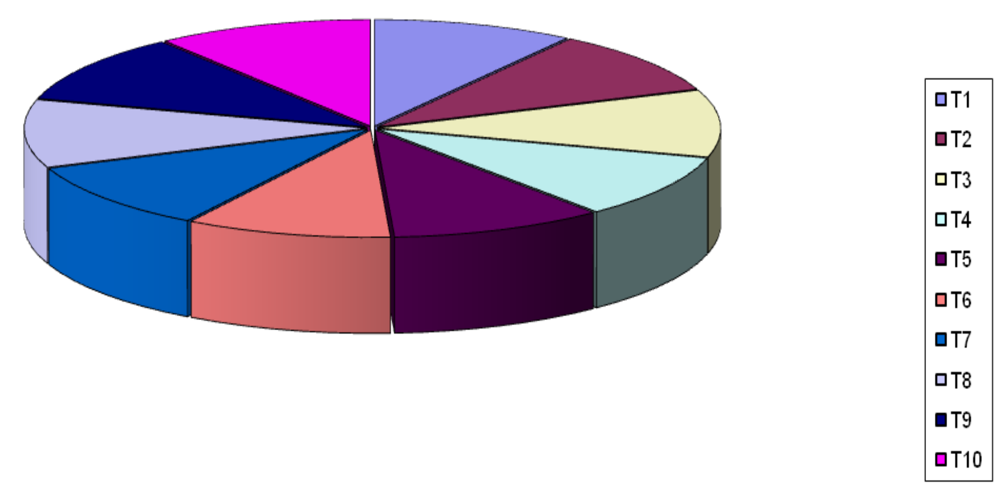

Fig.14 Effects of Nutrients and Plant growth regulator on Yield (t ha-1)

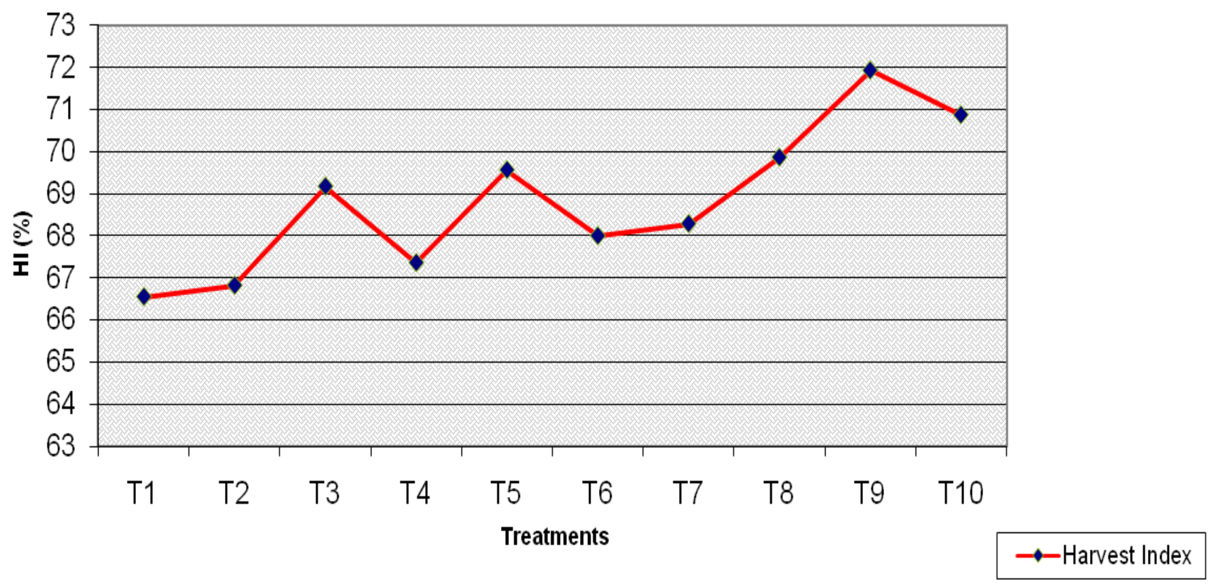

Fig.15 Effects of Nutrients and Plant growth regulator on Harvest Index (%)

Plate:1&2. General View of the Experimental Field

Plate:3. T_1-Control, T_9-KCl:1%, B:0.5%, Br:0.5 ppm on 50 & 75 DAS
T_{10}-KCl:1%, B:0.5%, on 50 & 75 DAS

Plate:4. T_1-Control, T_8-KCl:1%, B:0.5%, Br:0.5 ppm on 50 DAS
T_5-B:0.5%, on 50 & 75 DAS