PHENOLOGICAL STUDIES ON DRAGON FRUIT (*Hylocereus polyrhizus*) IN RESPONSE TO NITROGEN AND AGRO-ECOLOGICAL CONDITIONS OF NAGALAND

Thesis

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of

Doctor of Philosophy

in

Horticulture (Fruit Science)

by

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DECLARATION

I, **KOSGI MOUNIKA,** hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

This is being submitted to SAS, Nagaland University for the degree of Doctor of Philosophy in Horticulture (Fruit Science).

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CERTIFICATE – I

This is to certify that the thesis entitled **"Phenological studies on dragon fruit (*Hylocereus polyrhizus*) in response to nitrogen and agro-ecological conditions of Nagaland"** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Fruit Science) is the record of research work carried out by Ms. Kosgi Mounika, Registration No. Ph.D./HOR/00345, under my personal supervision and guidance.

The result of the investigation reported in the thesis has not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN HORTICULTURE (FRUIT SCIENCE)

This is to certify that the thesis entitled **"Phenological studies on dragon fruit (*Hylocereus polyrhizus*) in response to nitrogen and agro-ecological conditions of Nagaland"** submitted by Kosgi Mounika, Admission No. Ph-272/19, Registration No. Ph.D./HOR/00345, to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Fruit Science) has been examined by the Advisory Board and External examiner on …………………….

The performance of the student has been found **Satisfactory/Unsatisfactory.**

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Date:

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LIST OF ABBREVIATIONS/ SYMBOLS

%	Per Cent
cv	Cultivar
cm	Centimetre
ºC	Degree Celsius
N	North
E	East
W	West
S	South
et al.	And other
kg	Kilogram
g	Gram
ha	Hectare
No.	Number
SAS	School of Agricultural Science
mm	Millimetre
RBD	Randomized block design
S Em±	Standard Error Mean
LSD	Least Significant Difference
GAE	Gallic acid equivalent
Fig	Figure
N	Nitrogen
P	Phosphorous
K	Potassium
PM	Pig manure
FYM	Farm Yard Manure
ºBrix	Degree Brix

ABSTRACT

The present study **"Phenological studies on dragon fruit (*Hylocereus polyrhizus*) in response to nitrogen and agro-ecological conditions of Nagaland"** was conducted during 2021 to 2022 at Experimental Farm of Department of Horticulture, School of Agricultural Sciences, Medziphema Campus, Nagaland University. The findings of the different experiments are elucidated as follows:

Ten treatments of different doses of nitrogen and combinations of organic manures, common doses of phosphorous and potassium were applied to plants in the years of 2021 and 2022. [N_0 Control; N_{100g}/plant; N_{125g}/plant; N_{150g} /plant; 75% of N_{100g}+$FYM_{1.0\ kg}$/plant; 75% of N_{125g}+$FYM_{1.25\ kg}$/plant; 75% of N_{150}+$FYM_{1.5kg}$ /plant; 75% of N_{100g}+Pig $manure_{1.66kg}$/plant; 75% of N_{125g}+Pig $manure_{2.1kg}$/plant; 75% of N_{150g}+Pig $manure_{2.5kg}$/plant.] The pooled data of two-year study revealed that treatment with 75% of N_{150g}+Pig $manure_{2.5kg}$/plant (T_{10}) resulted with maximum N (393.35 kg/ha), P (41.46 kg/ha) in soil and maximum N (2.81%) in plant sample which was statistically at par with treatment 75% of N_{125g}+Pig $manure_{2.1kg}$/plant (T_9). Maximum cladode length (232.04 cm), number of areoles/cladode (79.32), flower length (31.07 cm), stigma length (14.06 cm), stamen length (12.42cm), pericarp length (16.60 cm), fruit weight (401.26 g), fruit length (8.50 cm) and fruit width (8.36 cm) also resulted with treatment 75% of N_{150g}+Pig $manure_{2.5kg}$/plant (T_{10}) followed by 75% of N_{100g}+Pig $manure_{1.66kg}$/plant (T_8) and 75% of N_{125g}+Pig $manure_{2.1kg}$/plant (T_9) were statistically at par with (T_{10}) in these fruit characteristics.

Flowering started in May and continued till October and peak flowering season was marked from May to August. Days taken from flower bud emergence to flower opening on an average was recorded as 16-20 days, and it took 29-36 days from anthesis to fruit ripening. Days taken from anthesis to fruit ripening and days taken from bud emergence to flower opening had high positive correlation with temperature. Fruit weight, length and width had high positive correlation with rainfall. The peak time of flower opening was recorded between 9:00 to 11:00 pm. Flower length (30.03 cm), petal length (12.51 cm), petal number (23.73), style length (14.50 cm), stamen length (11.54 cm), pericarp (14.82 cm) and perianth length (16.52 cm), TSS (16.30 °Brix), reducing sugar (6.98%) and total sugar (8.40%) in fruits were recorded highest in the month of June. Greatest fruit weight (441 g), fruit length (9.19 cm), fruit breadth (8.59 cm) was recorded in the month of July.

Stability of betacyanin pigment in peel and pulp of red dragon fruit (*Hylocereus polyrhizus*) was studied using three different pH levels (1, 3, and 6) and solvents (acetone, methanol and distilled water). Pigment extracted from peel by using distilled water (34.71 mg/100 g) as solvent at pH 3 showed highest betacyanin content (30.38 mg/100g), while maximum extraction from pulp was also recorded by using distilled water but at different pH level (pH 6) The pigment content in pulp was found higher than in peel. Betacyanin content obtained from pulp extracted by methanol at pH 6 was found maximum at initial days and decreased gradually when stored for the period of 10 days whereas extraction from distilled water remained stable even after 10 days of storage. Acetone showed the least stability in pigment colour.
Key words: *H. polyrhizus,* phenology, nitrogen sources, stability and betacyanin

CHAPTER I

INTRODUCTION

INTRODUCTION

Dragon fruit (*Hylocereus* spp.), a climbing cactus vine native to tropical regions of Mexico, Central and South America (Britton and Rose, 1963; Mizrahi *et al.,* 2010) is an emerging super crop among farmers for its economic value and rich nutrient content. It is commonly known as kamalam, strawberry pear, pithaya, night-blooming cereus, Belle of the night, Jesus in the cradle etc. around the world. It is a fast-growing, herbaceous, perennial, epiphytic, cacti crop which has been introduced into India in late 90's and is considered as a promising remunerative fruit crop and future crop of India (Pushpakumara *et al.,* 2005; Arivalagan *et al*., 2019). It adapts well in wide range of agro climatic zone due to its xerophytic nature and gives good returns from the second year of planting (Britton and Rose, 1963). With its high nutritional value, resilience against pests and diseases, minimal orchard maintenance, low water needs, frequent yields throughout the year and the potential for high output lasting up to 20 years, this crop has enticed numerous growers to cultivate it. This surge in cultivation has also amplified the fruit's export potential, catering to the growing market demand.

Dragon fruit has been cultivated commercially in many tropical countries since last 20th century and is well distributed in Israel, Vietnam, Taiwan, Nicaragua, Australia and the United States (Merten, 2003). Wakchaure *et al.* (2020) reported total area of 1, 12,264 ha with the production of 21, 00,777 Mt with Vietnam as the world's largest producer of dragon fruit in an area of 55,419 ha and productivity of 22-35 Mt/ha. Ninety-three per cent of world dragon fruit production has been reported from Vietnam, China and Indonesia. According to reports published by private organizations it is reported that dragon fruit production has been increased significantly in recent times (Chen and Paull, 2018).

Dragon fruit requires dry, frost free conditions and temperatures below 38°C for its successful growth which is prevalent in Southern, Western, and North Eastern regions of India making these areas more feasible for its cultivation. Currently, states which has started cultivation of dragon fruit on commercial scale are Karnataka, Tamil Nadu, Kerala, Andhra Pradesh, Telangana, Nagaland, Tripura, Assam, Meghalaya, Arunachal Pradesh, Maharashtra, Gujarat, Orissa, West Bengal and Andaman and Nicobar Islands. Total area under cultivation in India during 2014 was less than 400 ha (Karunakaran *et al.,* 2014) which presently has increased to 3000-4000 ha with a production of 12,000 MT, productivity of 8.0 to 10.5 Mt/ ha, which however is not sufficient for the growing demand (Wakchaure *et al.,* 2020).

The fruit belongs to the genus *Hylocereus* and is diploid (2n=22) (De Dios, 2004) it belongs to the family cactaceae which has climbing vines that cling to the substrate with their aerial roots and produce fruits covered with scales. It is a long day plant and has beautiful white flower which blooms at night hence nicknamed as "Queen of Night". At present four types of dragon fruit are contributing to the world market as table fruit *i.e.*, i) red skin, white flesh (*Hylocereus undatus*) (ii) red skin, red flesh (*Hylocereus polyrhizus*) (iii) red skin, purple flesh (*Hylocereus costaricencis*) (iv) yellow skin, white flesh (*Hylocereus megalanthus*). It is an ovoid berry with scales having green epidermis in immature stages and red or yellow skin when ripe with black seeds (Corredor, 2012; Bellec and Vaillant, 2011). It requires an average rainfall ranging from 500-1500 mm and can be grown up to 1700 m altitude. Temperature ranging between 20-30°C and soil pH 5.5-6.0 is considered suitable for its growth and development. Well drained loamy soils with rich organic matter are most suitable for growing dragon fruit.

It is an exotic fruit with high demand due to its rich source of nutrients, minerals and vitamins (Duenas *et al*., 2008) and considered as tropical rich food (Karunakaran *et al*., 2019). The nutritional constitution of dragon fruit is

8-9 mg/100 g vitamin C, 0.2-0.45 mg/100 g vitamin B3, 16-36 mg/100 g phosphorous, 6-10 mg/100 g calcium, 0.3-0.7 mg/100 g iron, 9-14 g carbohydrates, 0.1-0.6 g fats, 0.3-0.9 g fiber, 0.15-0.5 g protein. The skin contains 6.7 mg of betacyanin equivalent/100 g dry weight (Chong *et al.*, 2014). Betacyanin is classified as betalains compounds which have red pigments. Betacyanin extraction can be done using polar solvents such as ethanol, methanol and water. However, betacyanin can be easily degraded because of heat, pH and light (Tang and Norziah, 2007).

With the growing importance of dragon fruit cultivation in India, major emphasis should be given to standardize the fertilizer doses in different agro-climatic conditions in order to help farmers take up its cultivation on commercial scale and gain economic rewards as it is a nutrient loving plant. North Eastern India is considered as a hub of organic products because there is minimal or no use of chemical fertilizers by most farmers. The fertile soil and congenial climatic conditions in the region contribute as positive factor in the growing of several exotic crops including dragon fruit. Although dragon fruit belongs to cactaceae family, it requires water during critical periods of its growth because unlike other cacti it is from tropical rainforest. According to the studies conducted on dragon fruit for adaptability and production aspects by Karunakaran *et al.* (2014) it was reported that dragon fruit prefers dry tropical climate with optimum temperature of 20-29°C and can withstand temperatures up to 38-40°C and as low as 0°C for shorter periods. Heavy rainfall during flowering season may lead to flower and fruit drop and high temperatures exceeding 40°C may lead to flower burn. These conditions make the north eastern regions even more suitable for dragon fruit cultivation except during high rainfall season which may negatively impact flowering and fruit setting.

Plant nutrition is one of the most important factors that plays crucial role in growth, yield and quality attributes in dragon fruit. Indiscriminate and prolonged use of chemical fertilizers without adding organic fertilizers deteriorated the health of soil and increase soil pollution by decreasing the microbial activity (Singh and Kallo, 2000). This calls for a holistic approach to maintain soil health as well as obtain high productivity in the crop grown. A new farming strategy therefore entails a plant nutritional package which would provide all elements through both organic, inorganic and biofertilizers which would not only reduce the soil pollution but also produces quality produce with greater production and productivity and also keep the production cost at bearable level to the average farmer. Several reports show that the integration of organic and inorganic fertilizers proved superior to the sole application (Abusaleha and Shanmugavelu, 1988). Use of biofertilizers along with organic and inorganic fertilizers created a lot of impact in horticulture. Most soils in the North East region of India are acidic in nature where phosphorous content in soil is high but is not be readily available to the plant. Organic acids secreted during organic matter decomposition and phosphobacteria makes the insoluble form of phosphorous to available form and saves up to 30-50 kg of superphosphate (Chen *et al*., 2006). Nitrogen occupies a conspicuous place in plant metabolism system and it plays a key role in agriculture by increasing crop yield. It is a part of protein, important constituent of protoplasm, enzymes, the biological catalytic agents which speed up life processes. Nitrogen is also present as a part of nucleoprotein, amino acids, amines, amino sugar, polypeptides and other organic compounds in plants.

The red or red-violet colour of dragon fruit is due to a pigment called betacyanin belonging to the betalin group (Halimfanezi *et al.,* 2020) which can become a game changer for food industry as a natural food colorant. Betalins are classified into two major groups betacyanin and betaxanthin, of which only the former is present in dragon fruit and latter is devoid of it (Stintzing *et al*., 2002., Wybraniec and Mizrahi, 2002). Among *Hylocereus* genus, there are seven identified betacyanins which have same absorption spectracontributing to deep purple colour of pulp. Until now betacyanin has highly been exploited from red beet but due to its earthy odour caused by geosmin and pyrazine derivatives, and contain nitrogen, there is a demand for an alternative (Woo *et al.,* 2011). Raised awareness for consuming organic food, the demand for natural food colorants has increased and them being highly unstable, easily degraded and heat liable has become a challenge for extraction and storage of pigments. Betalins are prone to oxidation because of its antioxidants. Preventing oxidation during extraction and storage is highly needed (Woo *et al*., 2011). Stintzing and Carle (2004) reported that betacyanin are classified into four kinds *i.e.,* betanin, gomphrenin, amaranthine and bougainvillea. Betacyanin found in dragon fruit is a polar solvent and has high antioxidant activity (Naderi *et al.*, 2012). Betacyanin pigment degradation majorily occurs due to heat, light, pH, moisture and oxygen which effects the storage and stability (Liu *et al.,* 2008). These limitations may restrict the use of natural plant pigments in food industry.

Considering the importance of this emerging crop with high potential in commercialization it was a felt need to conduct the present study entitled "Phenological studies on Dragon fruit (*Hylocereus polyrhizus*) in response to nitrogen and agro-ecological conditions of Nagaland" which would augment dragon fruit crop cultivation and add fillip to the economy of average farmers. The objectives under this study were:

i. To evaluate optimum dose of nitrogen through various sources for growth and development of dragon fruit grown under mid-hill condition of Nagaland

ii. To study the phenology of dragon fruit grown under mid-hill condition of Nagaland

iii. To study the stability of betacyanin pigment in *Hylocereus polyrhizus* peel and pulp

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In this chapter an attempt is being made to review the works done by various workers on different aspects of dragon fruit. The literature pertaining to dragon fruit are very few especially under Indian agro-climatic conditions. Therefore, some reports on similar crop have also been reviewed in support of the proposed investigation.

Nitrogen on growth and development

Muchjajib *et al.* (2010) reported that application of $N_{24}P_{24}K_0$ per plant was found optimal in production of maximum fruit weight in pitaya. A study in Nigeria resulted in increased stem girth, plant height, fruit weight with the application of pig manure and NPK alone or in combination (Awosika *et al*., 2014).Similarly in cowpea, combination of NPK and pig manure gave best results compared to sole application producing greater plant height and production in Nigeria (Olusegun, 2014).Similar results were obtained in strawberry (Sharma *et al*., 2019) with combined treatments of organic and inorganic fertilizers as compared to sole application. In Chittagong Hill tracts, Chakma *et al.* (2014) reported maximum plant height (390 cm) with application of N_{400} P_{230} K_{185} g/pillar and greater plant circumference (19.24 cm) with N_{810} P_{465} K_{375} g/pillar. In a study by Akter *et al.* (2017) to develop fertilizer management package in Bangladesh reported that the maximum plant height (258.67 cm) was obtained with the treatment of Urea:100g/month; TSP: 100g/month; MOP:100g/month and 2kg manure/month. Ringphawon (2018) reported that poultry manure has a greater potential than the other organic manures for the vegetative growth of dragon fruit. Cladode length, diameter, and circumference, increased with increasing doses of poultry manure at 50% RDF, closely followed by FYM while areole number (48.33) was observed maximum with FYM at 50% and 25%. Application of FYM+NPK (75%) +Azotobacter+ PSB produced maximum number of branches per plant (7.61), thorns per plant and stem diameter (19.13cm) in an experiment conducted on dragon fruit (*Hylocereus undatus* L.) in Lucknow (Verma *et al*., 2019). There was maximum vegetative growth in dragon fruit (*H.Polyrhizus*) with organic and inorganic fertilizer application resulting in maximum plant height (47.78 cm), number of branches (4.22), main stem circumference (22.55 cm), plant canopy north to south (17.44cm^3), plant canopy east to west (20.38 cm^3) number of sprouting (6.33) and new shoots height (59.11) with application of NPK (50% RDF)+50% vermicompost followed by application of NPK (50% RDF)+50% poultry manure (Kumar *et al*.,2018). Kumar *et al.* (2019) reported that organic manures increased vegetative growth of dragon fruit (*Hylocereus polyrhizus)* cv. Red Jaina grown in Prayagraj. The treatment vermicompost 75% +FYM 25% produced maximum plant height (46.73 cm), number of branches (6.0), minimum days taken to first sprouting (20.03), new shoot height (39.16 cm), plant canopy north to south and east to west (21.36; 20.60 cm) and number of sprouting per plant (4.66). Herawati *et al*. (2021) studied the effect of organic fertilizers on growth of dragon fruit under Indonesian conditions. Treatments with different doses of cow manure, goat manure, chicken manure, sand, rice husk compost and control resulted with highest number of shoots (13.7) with cow manure and chicken manure recorded highest fruit weight (0.35 kg). Effect of organic manures and bio-fertilizers on growth of dragon fruit (white and red) was conducted by Siddiqua *et al.* (2021). Among all the treatments application of 100% N through vermicompost + PSB @ 10 kg/ha along with VAM @ 10 kg/ha recorded maximum plant height (385.83 cm and 395.83 cm), circumference (7.74 and 7.83) and stem diameter (19.55 and 19.74 cm) in both white and red flesh dragon fruit. Norfriandi *et al.* (2021) reported that cow manure had significant effect on fresh weight of the shoot, length of the shoot, highest number of shoots and dry weight of the shoot while application of KCl had no significant effect on the shoot length, number, dry and fresh weight of the shoot. A study conducted in Bengaluru using different organic manures and bio-fertilizers in red and white fleshed dragon fruit revealed that application of 100% N through vermicompost+PSB @10 kg ha^{-1}+VAM @ 10 kg ha^{-1} produced maximum height (409.85 cm), circumference (19.76 cm) and diameter (15.12 cm) was recorded in red flesh dragon fruit. Dey *et al.* (2022) conducted an experiment to study the effect of vermicompost and different organic growing media on morpho-physiological characteristics in dragon fruit (*H. costaricensis*) in West Bengal and reported that treatments with 1kg vermicompost along with 1.5kg farm yard manure/plant and 500g mustard cake/plant recorded maximum plant height (285 cm) and number of branches per plant (10). Effect of fertilizers, vermicompost, and farmyard manure on growth of red dragon fruit (*Hylocereus costaricensis*) was conducted by Rawat *et al.* (2022) at Lucknow and results revealed that the vegetative parameters like plant length (175.77 cm), number of areoles (27.67), stem girth (4.44 cm), circumference (15.33 cm), number of spines (4.44) and distance between areoles (5.75 cm) were recorded highest in the treatments with combined use of chemical and organic manures in the form of 75% RDF + 4 kg FYM/ pole. Samant *et al*. (2023) conducted experiment to study the effect of inorganic fertilizers on growth of dragon fruit in Tamil Nadu and reported greater vine length (2.96 cm), cladode girth (24.52 cm) and cladode length (67.21 cm) with application of NPK at 450:350:300 g/pole. Hariyanto *et al.* (2023) reported that combined use of nitrogen @100g and phosphorous @ 50, 75, and 100g/pillar increased the number of shoots, number of flowers and number of fruits in dragon fruit under Indonesian conditions. A study in Uttar Pradesh resulted in increase the maximum plant height (213.51 cm), stem diameter (12.80 cm), number of areoles per rib (71.15), number of spines per areoles (3.89), fresh weight of the shoot (331.91 g) and dry weight of the shoot (42.17 g) were recorded in the treatment with 300g NPK+1% Boron (50% main roots+50% aerial roots (Pandey, 2023).Similar results were obtained with the application of NPK at 450:350:300 g/pole which produced greatest length (2.86 m) and length of cladode (102.45 cm) in *H. undatus.*

Chakma *et al.* (2014) reported fruit weight (316.40 g), fruit length (9.27 cm) and fruit breadth (7.81 cm) in dragon fruit with application of N_{540} P_{310} K_{250} g/pole. In an experiment conducted in Southern Philippines (Gonzaga *et al.,* 2017) it was reported that increased application of N produced greater fruit weight where maximum fruit weight was obtained with the application of NPK: 120-60-60 kg/ha. Similar results were obtained by Akter and Rahman (2017) where maximum fruit weight (322.53 g), fruit length (12.21cm) and fruit breadth (7.74cm) was observed in the treatment Urea:200g/ 2months; TSP: 200 g/ 2months; MOP: 200g/ 2months and 5kg manure/ 4months. A study on phenology of dragon fruit revealed that the highest stamen length (11.25 cm) was found with application of N_{500} P_{400} K_{350} g/pole (Perween and Hasan, 2018). Rahman *et al*. (2021) reported that Banana cultivated in Assam showed increase in bio-chemical parameters like TSS, acidity, reducing sugars, non-reducing sugars and total sugars with application of organic manures such as FYM, vermicompost, microbial consortia as compared to NPK application. Significantly greater fruit length (7.95 cm), diameter (7.02 cm), fruit weight (240 g) and pulp weight (187.50 g) were recorded in dragon fruit which may have resulted with application of vermicompost along with FYM and mustard cake (Dey *et al*., 2022). An experiment was conducted by Pandey (2023) to study the effect of different doses of NPK and boron on flowering and fruiting of dragon fruit (*H. costaricensis*) revealed that treatment with 300g NPK+1% Boron (50% main roots+50% aerial roots recorded maximum fruit length (9.62 cm), fruit width (7.85 cm), fruit weight (264.33 g) and pulp percentage (77.17 %) while flower parameters like days from bud to bloom, flower opening hours, flower length were not much affected. A study conducted by Satish

(2023) at MPKV, Maharashtra on the influence of inorganic fertilizers on development of dragon fruit revealed that the maximum fruit length (19.23 cm), fruit diameter (8.00 cm), fruit weight (402.67 g) and pulp weight (316.76 g) were recorded maximum in the treatment with N_{450} P_{350} K_{300} g/pole whereas peel thickness (3.98 mm) and peel weight (89.90 g) was recorded highest in the treatment $N_{550:}$ $P_{450:}$ $K_{400.}$ Malsawmkimi *et al.* (2019) reported that the maximum fresh weight (106.33 g), dry weight and highest total nitrogen content (2.89%) of shoot in dragon fruit was recorded at 250ppm of IBA. Satish (2023) reported that application of N_{350} P_{250} K_{200} g/pole recorded maximum available nitrogen (220.90 kg/ha), phosphorous (18.31 kg/ha) and potassium (650.00 kg/ha) in soil whereas treatment with NPK doses of 450:350:300 gave maximum total nitrogen (1.71%), total phosphorous (0.44 %) and total potassium (1.81%) in cladodes.

Nitrogen on bio chemical characteristics

An experiment conducted by Muchjajib *et al.* (2010) in dragon fruit revealed that the maximum TSS (13.88 ºBrix) and minimum acidity (0.30%) was obtained in the treatment $N_{16}P_{16}K_{16}$ whereas maximum ascorbic acid (7.36 mg/100 g) was recorded in the treatment $N_{12}P_{24}K_{12}$ per plant. The chemical fertilizers had an effect on the total soluble solids but did not affect the content of vitamin C. Sitompul and Zulfati (2019) reported that the treatment with highest nitrogen supply resulted in the decrease of betacyanin content by 25% stating that nitrogen fertilization significantly influenced the betacyanin content in beetroot that decreased with increase in rate of nitrogen. Similar results were obtained by Pangestika *et al.* (2021) where betacyanin content in beet root was reduced by 80% when the doses of nitrogen increased. Application of N fertilizer resulted in increase of fresh weight of tuber leading to increase in betacyanin content in red beetroot. Effect of NPK and boron on quality of dragon fruit was studied by Pandey (2023) in Uttar Pradesh where plants treated with 300g NPK+1% Boron (50% main roots+50% aerial roots) recorded maximum TSS (15.5 ºBrix), titratable acidity (0.14%), ascorbic acid (8.44 mg/100g), reducing sugar (9.72%), non-reducing sugar (1.98%), total sugar (11.70%).Similar results were obtained with application of NPK at 550:450:400 g/pole in dragon fruit with maximum TSS (15.00 ºB), total sugars (11.00%), reducing sugars (9.13%), non-reducing sugars (2.07%) and minimum acidity (0.25%) whereas total phenol got recorded highest (13.20 mg/100g) with treatment of NPK at 350:250:200 (Satish, 2023).

Phenology of flowering and fruiting

Weiss *et al*. (1994) conducted experiment to study the flowering behavior and pollen requirements in climbing cacti and revealed that the flowering in *Hylocereus* occurred in two to three waves from May to October. Flowers started to open 1-1.5 before sunset and completely opened after sunset and closed by next morning and dehiscence of anther occurred 5 to 1 hour before flower opening. The distance between anther to stigma (2cm) was recorded in *Hylocereus* species. Nerd and Mizrahi (1998) reported that days taken from anthesis to fruit maturity had negatively correlated with temperature in yellow pitaya. Changes in the peel colour, increase in the fruit dimensions, increase in TSS, and decrease in acidity during the time of ripening were also recorded. De Dios (2005) reported that among all the species of the genus *Hylocereus, H.undatus ssp. Leutocarpus* with yellow fruit epidermis seen in the dry deciduous forests of Yucatan peninsula, had the sweetest fruits which possessed a TSS of 11.5 - 16.4º Brix. A detailed study on flowering and fruiting phenology in *Hylocereus* spp. (dragon fruit) was conducted by Pushpakumara *et al.* (2005) and reported that the flowering of *H. undatus* and *Hylocereus* spp. was seasonal and occurred from April to November with 4-7 cycles per year. Floral bud stage to anthesis took about 30 days. Bisexual flowers of dragon fruit were open from 6:30 pm and closed by

10:00 pm on the same day. However, they remained open till 12.00 noon of the next day if they were not pollinated. During flower opening and the receptive period, the stigma was positioned upright whilst after pollination it turned downward. Mallik *et al.* (2018) conducted a study to evaluate the influence of variety and flowering time on physio-morphological and chemical characters of dragon fruit. Two varieties (BAU Dragon fruit 1 and BAU Dragon fruit 2) and four flowering times (May, June, July, and August) were selected and found significant variation between two varieties. It was observed that at 38 days after fruit setting (DAFS), BAU Dragon fruit 2 produced the highest fruit length (10.01 cm), fresh weight (307.94 g/fruit), dry weight (24.85 g/fruit), pulp weight (168.98 g/fruit) and peel weight (91.32 g/fruit) as compared to another variety. The combined effects of variety and flowering time showed that August flowering of BAU Dragon fruit 2 produced maximum fruit length (10.74 cm) and peel weight (115.65 g/fruit) while May flowering of BAU Dragon fruit 2 produced maximum fresh weight (456.50 g/fruit) and pulp weight (302.12 g/fruit) as compared to other flowering time. In terms of time required to fruit maturity, August flowering BAU Dragon fruit 2 matured earlier (30.6 days) than June flowering (35.04 days). It was found that BAU Dragon fruit 2 exhibited better performances as compared to BAU Dragon fruit 1. Phenotypic characterization of different cactus species has been studied by Tel-Zur *et al.* (2011) at Israel. The phenological traits of different species recorded stated that *Hylocereus* fruits took 28-41 days from anthesis to reach maturity and fruit weight varied widely among different *Hylocereus* species. The highest was recorded in *Hylocereus undatus* (474 g) and lowest in *H. megalanthus* (77 g). Jiang *et al. (*2011) conducted experiment to study the phenology and fruit quality in yellow pitaya in Taiwanese conditions. The flowering season was recorded between mid- March and ended in the end of September. Fruits grown in winter recorded highest values in fruit weight compared to fruits grown in summer where fruits grown in summer weighed less than 100 g and winter fruits weighed between 25-300 g.

In studies on photo regulated bud formation in red pitaya., Jiang *et al.* (2012) reported that flowering occurred between May and October where short day length in summer inhibited the flowering in red pitaya and promoted more vegetative growth and flowering can be induced by increasing the day length. Short day lengths in summer and night breaking (artificial lights) in winter reversed the flower phenology in red pitaya. Patwary *et al.* (2013) conducted a study on the growth and development of two dragon fruit genotypes and reported that the flower bud emergence took place after 17 months in HUP 001, while it commenced in HUP 002 after 15 months. Number of days taken for flower bud to bloom was recorded as 28 days and the fruit matured after 33 days from anthesis in HUP 001 whereas it required 35 days for HUP 002 and fruits became matured after 32 days from anthesis. Numerous anthers were observed below the stigma with attractive white petals in both the varieties. The fruit weight ranged from 200-375 g in HUP 002 but 150-200 g in HUP 001. Fruit pulp colour was white in HUP 001 while red in HUP 002. Tran and Yen (2014) conducted study in Taiwan in red pitaya revealed that the flowering season started from beginning of May and ended in August with 6-7 flowering cycles per year recording 15-19 days from bud to flower and 30-32 days from anthesis to fruit maturity. The flower length varied from 34.1 to 28.6, pericarp length from 14.5 to 12.1 cm, stigma lobe number from 28.7 to 21.7 cm and distance between anther to stigma from 1.7 to 0.1 cm. Fruit set, and fruit characteristics in four red pitaya genotypes (‘Vietnam White’, Chaozhou 5’, ‘Orejona’, and ‘F 11’) showed that maximum fruit weight (402.6 g and 403.4 g) was recorded in hand self-pollination and open pollination respectively. Hand pollination significantly increased fruit set (95.8, 88.4 and 90.2%) and fruit weight (374.2, 281.8 and 416.3 g) in Chaozhou 5, Orejona and F11 respectively. Silva *et al.* (2015) reported that time taken from bud to anthesis as 18 to 23 days and from anthesis to harvest as 34 to 43 days in red dragon fruit under Brazilian conditions under 50% shade indicating shading affected the formation and production of flower buds. In Culiacan valley, Mexico Osuna-Enciso *et al.* (2016) reported that the flowering in *Hylocerus undatus* started in June and continued till October and 5-7 waves of flowering was observed in a year. Fruits recorded 4 weeks to reach maturity from anthesis in summer and 6 weeks in autumn and ranged between 372 to 638 g with 55.1 and 72.2% pulp. It was found that the onset of flowering was associated with temperature and relative humidity. In Sri Lankan conditions Warusavitharana *et al.* (2014) reported that average fruit weight ranged between 406.7-5568 g, peel thickness between 2-3.5 mm, length, width and girth varied from 111.3-14.2 cm and 8.2-9.5 cm and 25.5-29.1 cm respectively. Rabelo *et al.* (2020) studied reproductive phenology of yellow pitaya (*Selenicereus megalanthus*) in a high-altitude region in Brazil and recorded that the time between floral button formation until anthesis ranged from 46 to 55 days and the time from flower fertilization until fruit ripening ranged from 96 to 110 days and concluded that the reproductive cycle of *S.megalanthus* is longer than *H.undatus and H.polyrhizus*, ranging from 147 to 166 days from floral formation to fruit harvest. Flower phenology in red pitaya in Taiwan was reported by Ha *et al*. (2018) stating that the flowering season was recorded between June to October with 3 to 6 waves and was associated with high temperatures and number of days taken from bud to flower was recorded as 14-18 days and number of days from anthesis to fruit maturity as 27-33 days. Muniz *et al.* (2019) studied the floral biology of two species of pitaya (red and white) in Brazilian conditions and reported that the flower of red pitaya are green with red bracts, actinomorphic, hermaphrodite, pedunculate with floral buds originating at the spine base with bud length recorded as 25.2 cm. Stigma was found positioned above stamens. Number of days taken from bud to pre-anthesis was noted as 14 to 18 days. The time of flower opening was recorded between 2:00 pm to 8:00 pm. A phytotron experiment conducted in Taiwan for floral bud regulation revealed that revealed that increase in temperature showed no effect on vegetative bud emergence but enhanced the reproductive bud development thus indicating that long photoperiods initiated the reproductive bud development but for bud emergence warmer temperatures were required. The optimum required temperature for bud emergence and development was recorded as 32 /22 ºC and minimum 29/19ºC (Chu and chang, 2020). Ortiz and Takahashi (2015) conducted a study on pitaya fruit quality and observed that, the better time for harvesting pitaya is between 25 and 32 DAA to avoid the commercial loss. A detailed study on white and red flesh pitaya in Gujarat was conducted by Parmar *et al*. (2020) and revealed that fruit length varied between 9.51 and 7.66 cm, fruit diameter between 7.19 and 7.14 cm and fruit weight between 265.86 and 260.7g. A study on flowering pattern and fruit production of red pitaya under Malaysian conditions revealed that the peak flowering season was recorded from April to September and average fruit weight recorded as 211 to 334 g (Then *et al.*, 2020). Similar study in Kerala was reported by Sethunath *et al.* (2019) with flowering period recorded between March and continued till October and days taken from bud to flowering varying between 12-15 days and 23-25 days from anthesis to harvest of fruit. The time of anthesis was noted as 10:00 pm. Abirami *et al.* (2021) studied the distinguishing characters of three dragon fruit species suitable for growing in Andaman and Nicobar Islands and reported that the highest variation was observed in pulp weight (88.7) and the lowest in the distance of anthers below the stigma (3.3). Fruit and pulp weight (g) ranged from 26.5-419.3 and 10.3-258.8. Days from anthesis to fruit maturity ranged from 19.3 to 25.6. Flower length was recorded in the range of 18.36-23.22 cm and style length ranged from 7.02-13.42 cm. Days to anthesis ranged between 29.8-37.3 and number of stigma lobes were highest (28.2) in *H.undatus* and lowest (20.3) in *H. costaricensis.* Trong *et al.* (2022) reported that red pitaya took 32 days to attain maximum weight from the day of anthesis with fruit length and diameter ranging between 13.45 and 7.82 cm. similarly Singh *et al.* (2022) reported fruit weight (428.0 g), longitudinal diameter (107.7 mm), transverse diameter (82.3 mm), pulp weight (298.3 g) and peel thickness (3.03 mm) in red flesh dragon fruit stating that developmental stages and climatic factors influence the mineral content of the fruits. High temperature effect on flowering in pitaya was studied by Nerd *et al.* (2002) in Israel where the results shown that the high temperatures inhibited the flowering in red and white pitaya and warm areas with temperatures above 32 to 38°C are not suitable for dragon fruit growth. Flowering occurred in summer and autumn at coastal regions but only in autumn at valley regions. Dansena and Sharma (2023) reported maximum fruit weight 434.10 g, pulp weight 310.21 g, peel weight 104.79 g, pulp to peel ratio is 2.95, length (11.3 cm) and diameter (6.6 cm) in red flesh dragon fruit in Chhattisgarh. Floral behavior of *Hylocereus costaricensis* studied at West Bengal revealed that, number of days taken from bud to flower opening ranged between 12-18 days and the flower opening and closing hours recorded between 5:42 pm to 7:28 pm and 6:55 to 8:45 am. It was also found that the flower of *Hylocereus costaricensis* has free calyx and corolla, hermaphrodite, free stamens (numerous) and inferior ovary (Devi *et al.*, 2023). Lalduhsangi and Mandal (2023) reported that the fruits attained maximum maturity at 35 days after anthesis and recorded maximum fruit length and diameter (77.25 and 70.25 mm), fruit weight (211.80 g), pulp weight (119.36 g) and peel weight (108.00 mm) in red flesh dragon fruit.

Quality characteristics

Antioxidant study of pulps and peels of red and white dragon fruit was conducted by Nurliyana *et al.* (2010) at Malaysia and the results revealed that total phenolic content was recorded highest in peels compared to pulps of red and white dragon fruit. Total phenolic content was recorded highest in peels of

H. undatus (36.12 mg/100 g) compared to *H.polyrhizus* (28.16 mg/100 g) but the phenolic content in pulp was recorded highest in *H.polyrhizus* (19.72 mg/100 g). Jamaludin *et al.* (2011) reported a significant increase in soluble solids concentration and titratable acidity with the continuous increase in betacyanin content as days after pollination progressed. The physico-chemical and betacyanin accumulation of red-fleshed dragon fruit changed as fruit developed, matured and ripened. The total soluble solids (TSS) recorded highest in May flowering of BAU Dragon fruit 2 in Bangladesh (Mallik *et al.*, 2018). Similar study was reported by Patwary *et al*. (2013) in H. *undatus* in Bangladesh (12.0 and 11.4 % TSS) and Warusavitharana *et al*. (2014) in Sri Lanka. Islam *et al*. (2012) reported bio-chemical components in fresh dragon were analyzed and recorded as TSS (11 ºB), reducing sugars (4.50%), total sugars (8.00%), acidity (0.45%), non-reducing sugars (3.50%) and vitamin C (9.90%). Chang *et al*. (2016) reported that shading treatments helped in reduction of sun burn, improved cladode colour, increased fruit length, and reduced total soluble solids. In addition to that it influenced the peel and pulp betacyanin content by accumulating the pigment one or two days earlier compared to control when grown under 50% and 75% shade. A study on fruit quality of red pitaya was reported by Osuna-Enciso *et al*. (2016) in Mexico and recorded TSS (14ºB), acidity (0.6%) and TSS/acid (26.2). Similarly, Parmar *et al.* (2020) reported TSS (9.40 & 11.60 ºB), total sugars (8.62 & 9.19 %), reducing sugars (8.62 & 9.19 %), non- reducing sugars (4.36 & 4.12%), acidity (0.45 & 0.42%) and ascorbic acid (9.95 & 9.54 mg/100g) in white and red flesh pitaya in Gujarat. Abirami *et al.* (2021) conducted experiment in Andaman and Nicobar Islands in three *Hylocereus* species and reported TSS in *H.undatus* as 11.2º Brix, 9.1º B and 15.9º B for *H.costaricensis* and 18.3º B for *H.megalanthus.* Titratable acidity was recorded in the range of 0.16 to 0.28 % in all the three species and phenol (71.3-161.3) content was observed highest in peels than pulp (32.5-130.0 and 45.0-258.2) of fruit indicating higher antioxidant potential. Similar study was conducted by Arivalagan *et al.* (2021) in Bangalore in *H.undatus* and *H.polyrhizus* and the pH, TSS, total sugar, moisture, ash, protein, and dietary fibre content varied between 4.8 and 5.4, 8-12%, 5.13-7.06%, 82-85%, 0.90-1.1% and 0.8-1.0%, respectively. Total phenolics and flavonoids content varied between 25 and 55 mg GAE and 15-35 mg CE per 100 g, respectively, vitamin C was found maximum (6 mg/100g) and concluded that *H. polyrhizus* have a significantly high quantum of phenolics and antioxidant potential than *H.undatus.* Attar *et al.* (2022) reported that total phenolic content was found higher in red pitaya compared to white pitaya. Total phenolic content of red flesh dragon fruit was recorded as 16.66 GAE/100g and total sugars as 11.25%. The developmental study in semi-arid regions of India recorded maximum total sugars (16.73 mg/100 g), vitamin C (22.9 mg/100 g), betalains content (17.08 mg/100 g) and total phenol (72.69 mg catechin equivalent 100 g) at 45 days after anthesis in red flesh dragon fruit. Similarly in *H. undatus* the maximum TSS (12.65 ºBrix), acidity (0.13%), total sugars (9.70%), reducing sugars (9.03%), TSS: acid ratio (99.22) and ascorbic acid (24.79 mg/100g) were recorded 35 days after anthesis.

Stability of betacyanin pigment in both peel and pulp

A study in *Hylocerus polyrhizus* resulted that acidified juice with citric acid around pH 4 heated at 80ºC resulted in less degradation of pigment compared to crude juice (Vaillant *et al*. (2005). Similarly, in Germany Herbach *et al.* (2006) reported that stability of the betacyanin pigment was influenced by additives and pH levels. Pitaya juice at pH 4 with 1% ascorbic acid gave best results and upon subjecting to thermal treatment the degradation of pigment was found at pH 6. Isolation of betacyanin pigment from *Opuntia stricta* fruits was studied by Castellar *et al.* (2006) in Spain where water and ethanol: water were used as solvents for extraction. The highest betacyanin extract was obtained from water compared to ethanol: water. Tang *et al.* (2007)

reported that the pulp of red flesh dragon fruit has high pigment retention than peel and the pigment was more stable at pH range between 5 -6. In an experiment conducted in *Hylocereus polyrhizus* (Rebecca *et al.,* 2010) it was reported that water: weight ratio of 1:1 was found best for pigment extraction and betacyanin has high tolerance towards certain factors like temperature, light and pH. Kunnika and Pranee (2011) reported that the pigment content in peel was higher than the pulp of red flesh dragon fruit and pH range from 4-6 gave more colour retention in peel compared to other ranges at 7 days storage period. An experiment conducted by Woo *et al*. (2011) in *Hylocereus polyrhizus* revealed that light, temperature and pH had significant effect on color degradation of which light played major role. Samples stored at 4°C without light exposure gave the best results compared to other at three-week storage period. Lim *et al*. (2011) reported the effect of extraction parameters on yield of betacyanin pigment from *Hylocereus polyrhizus* pulp at Malaysia, the results revealed that temperature, pH and exposure time had significant effect on yield of betacyanin pigment, of which highest extraction was obtained when the samples were heated at 70°C at pH 6 for 5 minutes. A detailed study on effect of light, temperature, pH and stability of betacyanin pigment in *Basella alba* was conducted by Reshmi *et al*. (2012) and reported that increase in pH degraded the betacyanin pigment and pigment was found stable at pH range of 4.1 and 6.0 in the absence of light. Betacyanin pigments are stable under neutral and weakly acidic conditions and the pH above 7.5 showed decrease in pigment colour. An experiment on evaluation of solvent extraction of Amaranthus betacyanin was conducted by Chong *et al*. (2014) in Malaysia where water, methanol and ethanol were used as solvents of which water was found to be the best solvent in *Amaranthus gangeticus* and ethanol for *A.blitum.* An investigation was carried out by Wong *et al.* (2015) reported that that highest betacyanin content was recorded at pH 4 at 65°C for 30 minutes. Light resulted in degradation of pigment compared to samples stored in dark.

Priatni and Pradita, (2015) reported that five hours in room temperature resulted in decrease of betacyanin content to 10.44% in methanol while betacyanin content in water extract was decreased about 22.58%. Stability of betacyanin extract from red dragon fruit was influenced by the kind of solvent, pH and room temperature. A study for detecting betacyanin pigment stability from red pulp and peel of dragon fruit was conducted by Abdul Razak *et al.* (2017) and reported that eighty percent acetone used as a solvent for extracting pigment from pulp at pH 1 gave best results compared to other treatments. Pigment concentration was high in pulp compared to peel. Jahan *et al*. (2021) reported that pH plays a significant role in colour degradation in beetroot and the pH range 3-6 was able to preserve the colour of the pigment whereas degradation was observed at pH range between 8-10.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation entitled "Phenological studies on dragon fruit (*Hylocereus polyrhizus*) in response to nitrogen and agro-ecological conditions of Nagaland" was carried out during the year of 2021 and 2022 has been conducted in the research experimental block of Department of Horticulture, School of Agricultural Sciences, Medziphema Campus, Nagaland. The detailed information on materials used and methods adopted during the field experiment and laboratory analyses are described in this chapter under following headings and sub headings.

3.1 General information

3.1.1 Experimental site

The present experiment was conducted in Experimental Farm, School of Agriculture Sciences, Nagaland University, Medziphema campus, situated at 25° 45' 53" N latitude and 93° 53' 04" E longitudes at an elevation of 310 m above sea level.

3.1.2 Climate and soil

The prevailing climatic condition of Medziphema is humid and falls under sub-tropical region with an average annual rainfall ranging from 2000-2500 mm. The mean temperature ranges from 21° to 32° C during summer and rarely goes below 8°C in winter. The soil is sandy loam, acidic in nature with pH ranging from 4.5 to 6.5. The details of meteorological data during the period of investigation are presented in table 3.1. and soil characteristics in table 3.2.

3.1.3 Source of planting material

Rooted cutting of dragon fruit (*Hylocereus polyrhizus*) was initially procured from progressive farmer's field and planted in Experimental Farm at SAS. Multiplication of plants were done through cuttings which were used in planting in the field for the present investigation. The established field of dragon fruit with three-year-old plants were also used for the phenological studies in the present experiment.

3.1.4 Field preparation and planting

The experimental field was cleared of trees and shrubs and deep ploughing was done to remove roots and perennial weeds. RCC Concrete pillars of 6.5 feet were purchased along with rubber tyres which were fixed in the field with concrete and boulders for dragon fruit plants to train on. These were placed at 6 m and 6 m apart. Four cuttings of uniform growth and vigour were planted on each pillar and allowed to train on the pillar till plants reached the tyre on top over which the growing cladodes were allowed to hang.

3.1.5 Cultural practices

The basin area of each plant was kept weed free along with the interspaces between the pillars. Irrigation was provided uniformly for all plants at 2-3 days interval during periods of drought in summer and once in a week during winter season while no irrigation was provided during rainy season as there were sufficient moisture in the field. Regular monitoring was done for insect and pest attack and prophylactic care was given against fungal and bacterial diseases from time to time with spraying of neem-based pesticides and bavistin (Carbendazim) @ 2 ml/liter of water.

3.1.6 Nutrient application

The nutrients *i.e.,* nitrogen (N), phosphorus (P) and potassium (K) were applied in the form of urea, single super phosphate and muriate of potassium, respectively. The different does of organic fertilizers (Farm yard manure and Pig manure) were applied in the month of March followed by inorganic fertilizers in the month of May. Nitrogen was applied in split doses. Doses of FYM and Pig manure were calculated on basis of N content in the recommended dose of fertilizers (RDF) (N: P: K)-135:78:63g/plant. Common doses of P_{50g} and K_{75g}/plant was applied to every plant in the fields. PSB @ 30 g/pillar was supplied in equal doses to all treatments. Standard doses of inorganic fertilizers as described above were applied in the plants where phenological studies were carried out while the other field was applied with different levels of various sources nitrogen and standard doses of phosphorus and potassium. Farm Yard manure (FYM) and pig manure used for the experiment was collected from Livestock Production Management farm, SAS.

3.1.7 Collection and preparation of soil samples

Soil samples of the field before any application of fertilizers or manures was collected following standard procedure and analysed for available nutrient contents. The soil samples were collected at pre-flowering stage from each treatment and evaluated for available NPK in each season. A composite sample was prepared, thoroughly mixed and analysed to determine the nutrient status of the soil. The soil samples were spread evenly and big soil clods were crushed. After drying, pounding was done with wooden pestle and mortar to break the soil aggregates. The crushed samples were passed through 2 mm (8 mesh) sieve.

3.1.7.1 Available soil nitrogen (kg ha^{-1})

Available nitrogen was estimated by Kjeldahl's method as described by Jackson (1973).

3.1.7.2 Available soil phosphorous (kg ha^{-1})

It was determined by Olsen's method, using spectrophotometer as described by Jackson (1973).

Table 3.1 Meteorological data recorded during the period of crop investigation

Month	Temperature(°C)				Relative Humidity (%)				Rainfall (mm)		Sunshine (Hours)	
	2021		2022		2021		2022		2021	2022	2021	2022
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.				
May	32.80	21.91	30.50	21.90	90.00	58.00	92.00	71.00	85.42	224.41	4.70	4.00
June	33.10	24.30	32.00	23.92	93.00	69.00	95.00	72.00	117.40	160.81	3.40	2.60
July	33.31	24.82	33.61	24.31	92.00	72.00	92.00	69.00	272.20	375.82	3.90	5.00
August	32.60	24.62	33.30	24.13	93.00	72.00	94.00	70.00	138.80	261.81	3.20	4.80
September	34.00	23.50	33.10	23.80	94.00	68.00	94.00	68.00	98.70	116.20	3.10	4.20

Source: ICAR Regional Research Centre Jharnapani, Nagaland

Table 3.2 Soil fertility status of the experimental farm site

Parameters	Value
pH	5.3
Organic Carbon	0.6 %
EC	0.37 dS/m
Available Nitrogen	341 kg/ha
Available Phosphorous	29.8 kg/ha
Available Potash	179 kg/ha
Available Sulphur	8.2 ppm
Available Zinc	0.7 ppm
Available Manganese	2.2 ppm
Available Copper	0.5 ppm
Available Iron	8.8 ppm
Available Boron	0.7 ppm

3.1.7.3 Available soil potassium (kg ha^{-1})

It was extracted and estimated by neutral normal ammonium acetate method using flame photometer (Jackson, 1973).

3.2 Technical programme

3.2.1 **Experiment I** ***Nitrogen sources on growth and development of dragon fruit***

The experiment was laid out in randomized complete block design with three replications. Different levels of nitrogen with and without organic manures were applied to the one-year-old plants to evaluate the optimum dose for growth and development of dragon fruit plants.

Design of experiment	Randomized complete block design (RCBD)
Pillars	30
Number of replications	3

Plate 3.1. Preparation of field for dragon fruit planting up to fruiting

Treatments	
T_1	N_0 Control
T_2	N_{100g}/ plant
T_3	N_{125g}/plant
T_4	N_{150g} /plant
T_5	75% of N_{100g}+$FYM_{1.0\ kg}$/plant
T_6	75% of N_{125g}+$FYM_{1.25\ kg}$/plant
T_7	75% of N_{150g} +$FYM_{1.5\ kg}$/plant
T_8	75% of N_{100g}+Pig $manure_{1.66\ kg}$/plant
T_9	75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant
T_{10}	75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant

3.2.1.1 Observations recorded

3.2.1.1.1 Growth parameters

Cladode length (cm)

The length was measured from the base of the cladode to the tip of the uppermost point with the help of measuring tape. The average length was calculated for each treatment from all the replications and represented in centimeter.

Cladode diameter (cm)

The diameter of the cladode was measured by taking the distance of all the sides of the cladode. It was calculated by using the formula $C=\pi d$, where C= circumference and d=diameter. Average was calculated for each treatment and expressed in centimeter.

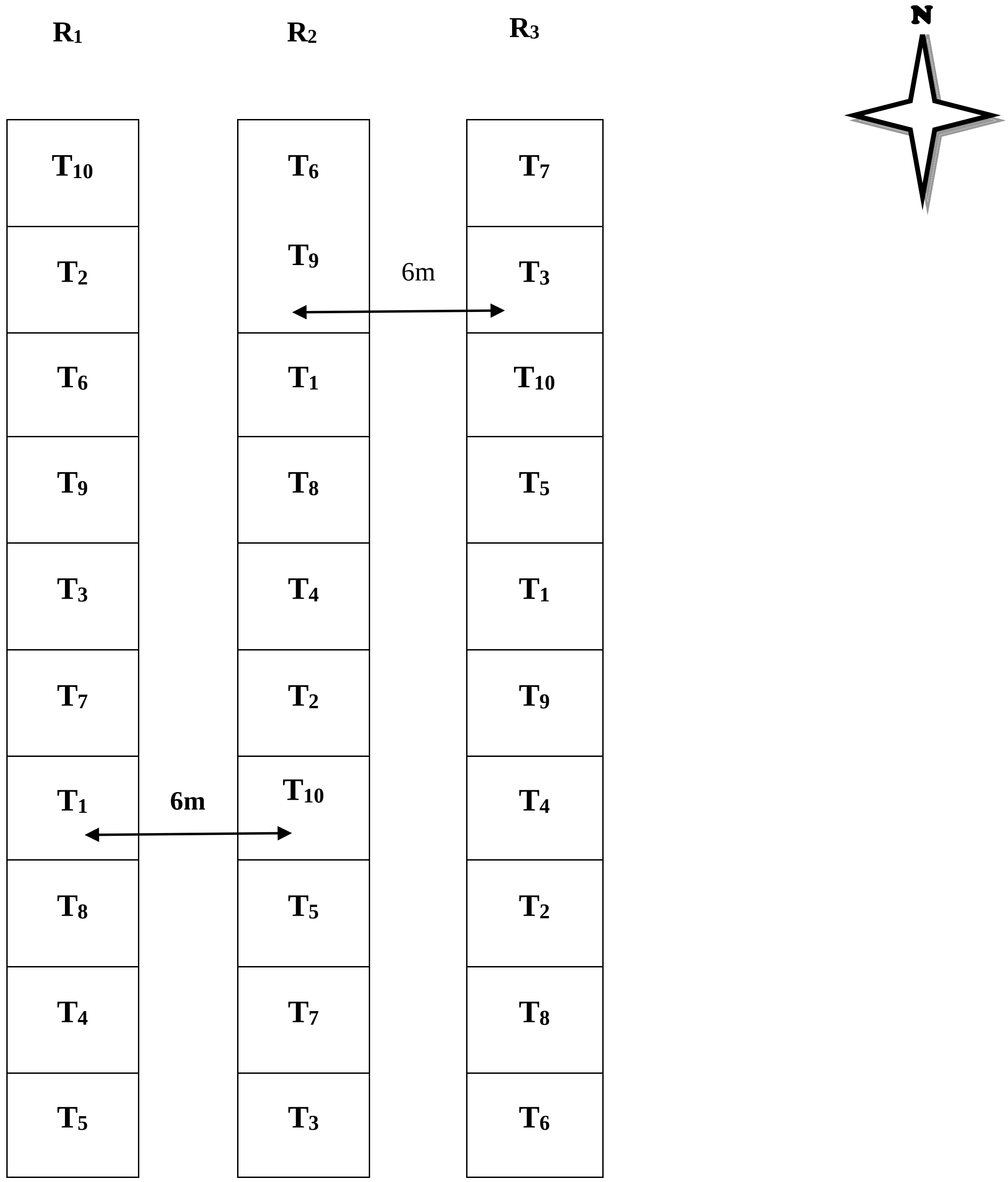


Fig 3.1 Plan and layout of the experiment

Cladode girth (cm)

The girth distance from all the sides of the cladode was taken as the circumference. Average was calculated for each treatment and expressed in centimeter.

Number of spines/areoles

For the present study the spine from the base, middle and top of the cladode were randomly selected for observation. Average was calculated for each treatment.

Number of areoles/cladode

For the present investigation the total number of areoles present on tagged cladode were counted and average was worked out for each treatment and expressed in number.

Distance between areoles (cm)

The distance from one areole to the adjacent areole was measured using a linear scale. Areoles on the middle portion of the cladode was taken for measurement and expressed in centimeter.

Area of areoles (mm^2)

Three samples of areoles were randomly selected and scooped out of the cladode and measured the area with the help of graph paper. Areole area was represented as mm^2.

Fresh weight of cladode (g)

Randomly selected cladodes from each treatment were removed and weighed immediately with the help of electronic balance (Sumo digital incorporation, IND- 09/ 2004/ 224) and average value was computed and expressed in grams.

Dry weight of cladode (g)

After recording the fresh weight, the same cladodes were cut into small pieces and placed in paper bag and dried in oven set to 65±2 ºC until weight becomes constant at hourly intervals. The average value was computed and expressed in grams.

3.2.1.1.2 Flower parameters

Pericarp length (cm)

Pericarp length was measured by using linear scale and average was worked out and expressed in centimeter.

Perianth length (cm)

Perianth length was measured by using linear scale and average was worked out and expressed in centimeter.

Flower length (cm)

The length of three flowers per treatment were measured by using jute thread and further measured using linear scale and average was worked out and expressed in centimeter.

Petal length (cm)

Petal length was measured by linear scale and average was worked out and expressed in centimeter.

Petal number (cm)

Petal number was taken by counting visually and expressed in number.

Stamen length (cm)

Stamen length was measured by using linear scale and was expressed in centimeters.

Style length (cm)

Style length was measured by linear scale and was expressed in centimeter.

Stigma lobe length (cm)

Stigma lobe length was measured by linear scale and average was worked out and expressed in centimeter.

Number of stigma lobes

Number of stigma lobes were counted visually and expressed in number.

Distance between stigma and anther (cm)

Distance between stigma lobe to the tip of the anthers was measured by using linear scale and average was worked out and expressed in centimeter.

3.2.1.1.3 Fruit parameters

Fruit size (cm)

The length and breadth of fruits was measured by using measuring scale, average was worked out and values were expressed in centimeter.

Number of fruits/pillar

The number of fruits for each pillar was counted and sum of all was expressed in number.

Fruit weight (g)

The weight of individual fruit was recorded by using electronic balance, average was worked out and expressed in grams.

Pulp weight (g)

Pulp weight was recorded by extracting pulp from the fruit and weighing it on electronic balance and was expressed in grams.

Peel weight (g)

Peel weight was recorded by measuring it on electronic balance after removing the pulp from it and expressed in grams.

Peel thickness (mm)

Peel thickness was measured by using Vernier calipers and expressed in millimeter.

3.2.1.1.4 Quality parameters

TSS (°Brix)

Total soluble solids, in the juice of representative sample was determined by using digital refractometer (range of 0-32^{0}Brix) with temperature correction and expressed in degree brix (°Brix).

Titratable acidity (%)

Pulp (20 g) from 15 fruit without symptoms of disease was homogenized in a grinder and the supernatant phase was collected to analyze TA. Five ml aliquot was mixed with one to two drops of phenolphthalein and was titrated against 0.1N NaOH. The appearance of light pink colour marked as end point as per method described in the manual of analysing of fruits and vegetables product by Ranganna (1991). The acidity was expressed in percentage by following formula:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of Alkali} \times \text{Equivalent weight of acid}}{\text{Volume of sample taken} \times 1000} \times 100$$

Total sugars (%)

Total sugar content in fruit juice was determined as per Lane and Eynon method (Ranganna, 1986). 50ml filtered juice was mixed with 100ml distilled water and neutralized with 0.1N NaOH solution using phenolphthalein as indicator and the solution was allowed to stand for ten minutes. Then 8ml of potassium oxalate solution was added and total volume was made up to 250 ml by adding distilled water. 5ml of the extract was taken in burette and titrated again 10ml mixed Fehling's (5ml Fehling's solution A+5ml Fehling's solution B) using methyl blue as indicator. The end point was indicated by decolourization of the solution.

$$\text{Total sugar (\%)} = \frac{\text{Factor of Fehling's solution x Dilution factor}}{\text{Titre x wt or volume of sample taken}} \times 100$$

Where, factor for Fehling's solution denotes the gram of invert sugar

$$\text{Factor} = (\text{Titre} \times 2.5)/100$$

Reducing sugars (%)

Reducing sugar was determined by following Lane and Eynon method (AOAC, 1994). Five gram of pulp was taken and crushed with a little amount of distilled water. The juice was then strained and volume was made up to 50ml using distilled water. The burette was filled with this solution. Meanwhile, in a conical flask, 2ml each of Fehling's A and Fehling's B solution were taken and 50ml of distilled water was added to it. It was heated to boil and a drop of methylene blue was added to it. Then it was titrated with the juice solution in burette until the end point by brick red colour with reddish precipitation appears. The burette reading was recorded.

$$\text{Reducing Sugar (\%)} = \frac{\text{Factor x Volume made up}}{\text{Titre Value x Volume made up}} \text{x100}$$

Ascorbic acid (mg/100g)

Ascorbic acid was estimated by volumetric method using 2, 6-dichlorophenol indophenol dye according to procedure suggested by Ranganna (1986) and expressed in mg/100 g pulp. To determine the ascorbic acid, 5 g of fruit pulp was dissolved in 3 per cent metaphosphoric acid and volume was maintained up to 100 ml. 5 ml aliquot was titrated against standardized 2, 6 dichlorophenol indophenol dye. The end point was marked by the appearance of pink colour. The ascorbic acid is expressed as mg of ascorbic acid per 100 g pulp of sample.

Ascorbic acid (mg/100g pulp)=

$$\frac{Titre\ value\ x\ Dye\ factor\ x\ Volume\ (100ml)}{Titre\ Value\ x\ Aliquot\ of\ extract\ for\ estimation\ x\ Weight\ of\ the\ sample} X100$$

Total phenols (mg GAE/100g)

Total phenolic content in dragon fruit peel and pulp was estimated by spectrophotometric method using Folin-Ciocalteu Reagent (FCR). Five grams of sample was homogenized adding 20 ml methanol (80%) in a pestle and mortar for 2-3 times. Extracts were pooled and volume was made up to 50 ml. Folin-Ciocalteu phenol reagent (0.2 ml) was added to 0.5 ml of extract in a test tube followed by 3.3 ml of distilled water. Allowed to stand for 2 minutes and added 1ml of sodium carbonate solution and mixed well and allowed to stand at room temperature for 30 minutes and absorbance was recorded in spectrophotometer at 700 nm (Singleton and Rossi, 1965).

Total phenol content (mg gallic acid equivalents/100g) =

$$\frac{OD_{700nm} \text{ x Std. value (µg/ OD) x Total volume of extract x 100}}{\text{Assay volume x weight of tissue (g) x 1000}}$$

Betacyanin (mg/100g)

Estimation of betacyanin content in both peel and pulp of dragon fruit was carried out by following method of Abdul Razak *et al.* (2017). Five grams of peel and pulp were mixed with solvent to make up the volume to 50 ml by using mortar and pestle. The treated pulp and peel were then subjected to centrifuge @3000 g for 10 minutes. Supernatants were collected and filtered. Absorbance of the sample was measured at 538 nm using spectrophotometer

UV-Vis against the blank reagent (same solvent used for sample). The absorbance readings were used to calculate betacyanin concentration (mg/ 100 g of fresh weight) in sample and was expressed as mg betacyanin content (BCE/100 g fresh weight) and was calculated by using equation

$$\text{Betacyanin (mg/100 g)} = \frac{\text{A(MW) x V x (DF) x 1000}}{\varepsilon \text{LW}} \text{ x } 100$$

A_{538}=absorbance at 537nm (^max), L (Path length of cuvette) = 1.0 cm, DF=Dilution factor, V= volume extract (ml), W=weight of extracting material (g). Ɛ is the molar extinction coefficient of betanin =60000 l / mol x cm) and MW (molecular weight) = 550 g/mol.

3.2.1.1.5 Collection and preparation of plant samples

One year old mature cladodes were collected from each replication, in the pre-flowering stage (first week of May) in both years. The cladodes were washed to remove dust and dirt and air dried, cut into small pieces and were dried at 60 ± 2 °C in hot air oven till all moisture was evaporated and two consecutive weights at one hour interval were found constant. The samples were finely ground to obtain homogeneity. Analysis was performed for nutrient content and estimated values were expressed in percentage.

Digestion of plant samples with di-acid mixture

A powdered sample of 0.5 g was pre-digested with 10 ml of concentrated HNO_3 and with 5 ml of di-acid mixture (HNO_3:$HClO_4$ in 9:4 ratio). It was kept overnight for digestion and then heated until evolution of white dense fumes leaving colourless clear solution in the conical flasks, cooled and the volume was made up to 100 ml with distilled water. The digested sample was used for estimation of P and K (Jackson, 1973).

Nitrogen (%)

Total nitrogen in sample was determined by Kjeldahl's method as described by Jackson (1973). In this method, a powdered sample of 0.5 g was digested with 10 ml of concentrated H_2SO_4 in the presence of digestion mixture (K_2SO_4:$CuSO_4.5H_2O$ proportion of 5:1) and digested under alkaline medium. The liberated NH_3 was trapped in boric acid containing mixed indicator and titrated against standard 0.01 N H_2SO_4. The nitrogen uptake was expressed in percentage.

Phosphorus (%)

The total phosphorus content in sample was determined by taking a known volume of the di-acid digested samples by adopting the Vanadomolybdate phosphoric yellow colour method as described by Jackson (1973). The intensity of yellow colour was determined in spectrometer (UV-VIS Spectrophotometer) at 470 nm. The Phosphorus uptake was expressed in (%).

Potassium (%)

The total potassium content of the di-acid digested samples was estimated by atomizing the digested and diluted sample to a calibrated flame photometer under suitable measuring conditions as described by Jackson (1973). The potassium uptake was expressed in (%).

Statistical analysis

The data collected and computed was completed by using SPSS software (Gomez and Gomez, 2010).

3.2.2 Experiment II Phenology studies of dragon fruit

Data on flowering and fruiting at different developmental phases was collected from three-year-old plant of *H. polyrhizus* and study on phenology of the flowering cycle was carried out by visual observations. The floral buds in each plant were tagged to determine the time between the floral button formation until flower anthesis and flower fertilization until fruit ripening. Thus, the flowering season and time for the development of the floral button and fruit was determined. Flower and fruit characteristics were recorded for every flowering and fruiting batches for the period of two years to monitor the peak flowering season and fruiting pattern. Treatments were designed according to the peak flowering season (month) and time of the flower opening (night time) and mean was worked out.

3.2.2.1 Treatment details (M=Month; T= Time)

$M_1 T_1$	May (8-9 pm)
$M_1 T_2$	May (9-10 pm)
$M_1 T_3$	May (10-11 pm)
$M_1 T_4$	May (11-12 pm)
$M_2 T_1$	June (8-9 pm)
$M_2 T_2$	June (9-10 pm)
$M_2 T_3$	June (10-11 pm)
$M_2 T_4$	June (11-12 pm)
$M_3 T_1$	July (8-9 pm)
$M_3 T_2$	July (9-10 pm)
$M_3 T_3$	July (10-11 pm)
$M_3 T_4$	July (11-12 pm)
$M_4 T_1$	August (8-9 pm)
$M_4 T_2$	August (9-10 pm)
$M_4 T_3$	August (10-11 pm)
$M_4 T_4$	August (11-12 pm)

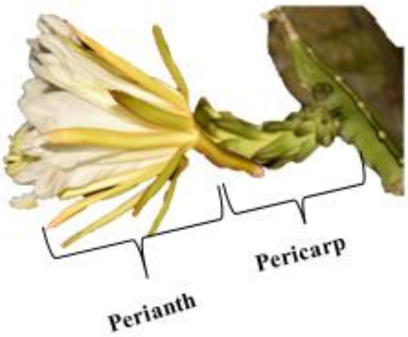
3.2.2.1.1 Flowering and fruiting characteristics

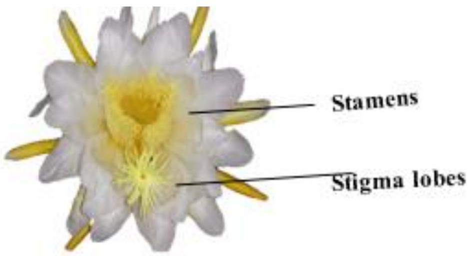
<u>Days taken from bud emergence to flowering</u>

Emerging buds at marble stage were tagged with date and the interval between tagging and date of opening of flower was recorded in days.

Pericarp length (cm), perianth length (cm), flower length (cm), petal length (cm), petal number, style length (cm), stamen length (cm), stigma lobe length (cm), number of stigma lobes and distance between stigma and anther (cm) were measured as described in the experiment I.

Source: Experimental farm, SAS, Nagaland University





Source: Experimental farm, SAS, Nagaland University

Days taken from anthesis to fruit ripening

The number of days taken from anthesis to fruit ripening was recorded and expressed in days.

Pulp percentage

Pulp was separated from the peel carefully; their weight was recorded and pulp percentage was calculated in relation to the total weight of the fruits.

$$\text{Pulp percentage (\%)} = \frac{\text{weight of the pulp}}{\text{Total weight of fruit}} \text{X100}$$

Fruit size (cm), fruit weight (g), pulp weight (g), peel weight (g) and peel thickness (mm) were measured as described in the experiment I.

Qualitative characteristics

TSS/acid

TSS/acid was calculated by dividing the TSS by titratable acidity.

Non-Reducing sugars (%)

The amount of non-reducing sugar of the product was obtained by subtracting reducing sugar from total sugars and multiplying the same with the factor 0.95.

TSS (°Brix), titratable acidity (%), total sugars (%), reducing sugars (%), ascorbic acid (mg/100g), total Phenols (peel and pulp) (mg/100g fresh weight) and betacyanin content (peel and pulp) (mg/100g of fresh weight) were measured as described in the experiment I.

Statistical analysis

The collected data were described by using descriptive statistics (range) and calculated by using MS Excel software.

Correlation analysis

Correlation analysis was carried out among the observational parameters by Spearman's correlation method by using the software SPSS. Analysis was carried out to know the effect of weather parameters like temperature, rainfall, relative humidity and sun shine hours on the flower and fruit parameters of dragon fruit.

3.2.3 Experiment III Stability studies of betacyanin pigment

The experiment was carried out at laboratory of Department of Horticulture, School of Agriculture Sciences (SAS, Medziphema Campus, Nagaland University where, freshly harvested dragon fruits (*Hylocereus polyrhizus)* were procured from experimental farm of SAS and evaluated for betacyanin content.

Experimental design	Factorial Completely Randomized block design (F-CRD)
Factors	Solvents (S) pH (P)
Treatments	9
Replications	3

Treatment details

S_1P_1	$S_{1:}$ Acetone; P_1: pH_1
S_1P_3	$S_{1:}$ Acetone; P_3: pH_3
S_1P_6	$S_{1:}$ Acetone; P_6: pH_6
S_2P_1	$S_{2:}$ Methanol; P_1: pH_1
S_2P_3	$S_{2:}$ Methanol; P_3: pH_3
S_2P_6	$S_{2:}$ Methanol; P_6: pH_6
S_3P_1	$S_{3:}$ Distilled Water; P_1: pH_1
S_3P_3	$S_{3:}$ Distilled Water; P_3: pH_3
S_3P_6	$S_{3:}$ Distilled Water; P_6: pH_6

Betacyanin estimation

Fruits were cleaned and cut in to small pieces using knife and were separated for peel and pulp. Three different solvents acetone (80%), methanol (80%) and water were used to extract the pigment. Five grams of peel and pulp were mixed with each solvent to make up the volume to 50 ml by using mortar and pestle. The treated pulp and peel were then subjected to centrifuge @3000 g for 10 minutes. Supernatants were collected and filtered. Absorbance of the sample was measured at 538 nm using spectrophotometer UV-V is against the blank reagent (same solvent used for sample). After the estimation of betacyanin content the pH of the samples was adjusted to 1, 3 and 6 by using 1M HCL and 1M NaOH by using pH meter until the desired pH is reached. The absorbance was measured using UV-Vis spectrophotometer at 537 nm. Samples were stored at room temperature covered with aluminum foil in the dark till the colour of pigment diminished and were assessed every day for betacyanin content.

The absorbance readings were used to calculate betacyanin concentration (mg/ 100 g of fresh weight) in sample and was expressed as mg betacyanin content (BCE/100 g fresh weight). It was calculated by using equation

$$\text{Betacyanin (mg/100 g)} = \frac{A(MW) \times V \times (DF) \times 1000}{\varepsilon L W} \times 100$$

A_{538}=absorbance at 537nm ($\wedge$max), L (path length of cuvette) = 1.0 cm, DF=Dilution factor, V= volume extract (ml), W=weight of extracting material (g). Ɛ is the molar extinction coefficient of betanin = 60000 l / mol x cm) and MW (molecular weight) = 550 g/mol.

Statistical analysis

The data collected during the investigation were statistically analysed by using SPSS software.

CHAPTER IV

RESULT AND DISCUSSION

RESULTS AND DISCUSSION

The findings and analysis of the current study titled "**Phenological studies on Dragon fruit (*Hylocereus polyrhizus*) in response to nitrogen and agro-ecological conditions of Nagaland"** are presented objective wise in this chapter. In order to make the findings more comprehensive, the results have been duly supported by respective tables and figures and discussed with findings of other workers on dragon fruit and other similar crops.

4.1 *Nitrogen sources on growth and development*

Effect of various nitrogen sources on growth parameters like cladode length, diameter, girth, number of spines, number of areoles, distance between areoles and area of areoles has shown below by using results, tables and graphs.

4.1.1 Cladode length (cm)

Marked variations were observed with respect to cladode length among the different treatments (Table 4.1). The recorded data has shown that the application of nitrogen through various sources had significant effect on cladode length of red dragon fruit. The maximum length (156.35 cm and 314.35 cm) was recorded during the year 2021 and 2022 respectively in the treatment 75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant (T_{10}). The minimum cladode length (56.27 cm) was recorded in the treatment N_{125g}/plant (T_3) in the first year which progressively increased in following year.

The pooled data for two years revealed that the treatment 75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant (T_{10}) recorded the maximum length (232.04 cm) and was found highly significant whereas the minimum was recorded in N_0 Control (T_1) (82.16 cm).

According to Verma *et al.* (2019) maximum plant height (129.30 cm) in dragon fruit was recorded in the treatment supplied with FYM+NPK+ Azotobactor + PSB whereas in the present investigation pig manure recorded significantly better results compared to the above treatment. This might be due to the high nitrogen content in the pig manure compared to FYM and vermicompost. The combination of inorganic and organic fertilizers might have improved the soil health thus resulting in creating favourable nutrient environment for plant growth (Lodhi *et al.,* 2017). Nitrogen plays a major role in cell elongation, cell division and protein synthesis which might have resulted in increasing the vine length (Maurya and Goswamy, 1985).

Olusegun (2014) supported these findings stating that pig manure in combination with NPK significantly increased the plant height. Nitrogen also plays major role in synthesis of plant growth hormones, amino acids which may have contributed to increase in the cladode length (Maynard and David, 1987).

4.1.2 Cladode diameter (cm)

The results pertaining to diameter of the cladode was recorded and presented in table 4.1 where, it was found that the diameter was significantly influenced by various sources of nitrogen. The maximum cladode diameter (4.34 cm) in 2021 was recorded in 75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant (T_9) but in 2022 it was recorded highest (5.82 cm) in 75% of N_{100g}+Pig $manure_{1.66\ kg}$/plant (T_8) while the minimum was recorded in N_{100g}/plant (T_2) (3.37 cm) and N_0 Control (T_1) (4.21 cm).

The pooled data for two years revealed that the maximum cladode diameter (5.02 cm) was recorded in 75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant (T_9) and the minimum in N_{100g}/ plant (T_2) (3.80 cm). Ringphawon (2018) reported that 25% pig manure gave best results regarding the diameter of dragon fruit compared to mineral fertilizers. This might be because of availability of more

Table 4.1 Effect of various nitrogen sources on physical cladode characteristics of dragon fruit

Treatments	Cladode length (cm)			Cladode diameter (cm)			Cladode girth (cm)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
N_0 Control	57.75	110.36	82.16	3.53	4.21	3.86	11.08	13.22	12.15
N_{100g}/ plant	63.24	154.14	105.33	3.37	4.24	3.80	10.93	13.33	12.12
N_{125g}/plant	56.27	157.01	106.06	3.65	4.35	4.00	11.52	13.67	12.59
N_{150g} /plant	58.96	179.02	117.46	4.04	4.66	4.35	12.69	14.65	13.66
75% of N_{100g}+ FYM $_{1kg}$ /plant	70.59	194.02	130.20	3.87	5.02	4.44	12.17	15.78	13.97
75% of N_{125g}+FYM $_{1.25\ kg}$/plant	85.61	187.35	135.27	4.18	4.84	4.51	13.13	15.22	14.17
75% of N_{150g} + FYM $_{1.5\ kg}$ /plant	94.28	216.58	154.04	3.91	5.27	4.59	12.30	16.57	14.43
75% of N_{100g}+ Pig manure $_{1.66\ kg}$/plant	121.76	236.03	178.69	3.93	5.82	4.87	12.37	18.28	15.32
75% of N_{125g}+ Pig manure $_{2.1\ kg}$/plant	153.01	281.69	215.65	4.31	5.73	5.02	13.55	18.01	15.78
75% of N_{150g}+ Pig manure $_{2.5\ kg}$ /plant	156.35	314.35	232.04	4.27	5.49	4.87	13.43	17.24	15.33
S Em±	2.85	6.53	2.44	0.09	0.04	0.05	1.61	0.57	0.50
CD at 5%	8.55	19.57	7.32	0.28	0.13	0.15	4.67	1.72	1.51

nutrients due to the addition of organic and inorganic fertilizers (Lodhi *et al.*, 2017).

4.1.3 Cladode girth (cm)

Data in table 4.1 indicated that different sources of nitrogen had significantly influenced the girth of the dragon fruit cladode. Application of 75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant (T_9) recorded the highest girth (13.55 cm) in the year 2021 but in 2022 it was recorded highest in (18.28 cm) 75% of N_{100g}+ Pig $manure_{1.66\ kg}$/plant (T_8) and minimum (10.93 cm) was recorded in N_{100g}/plant (T_2) in the year 2021 and N_0 Control (T_1) (13.22 cm) in 2022.

The pooled data for two years revealed that the maximum cladode girth (15.78 cm) was recorded in 75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant (T_9) and treatment 75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant (T_{10}) was found statistically at par with it. The minimum cladode girth was recorded in N_{100g}/plant (T_2) (12.12 cm).

The results are in agreement with Awosika *et al*. (2014) and Iren *et al*. (2016) where the combination of NPK and pig manure significantly increased the stem girth. This might be due to the increase in soil nutrients because of addition of organic manures, which helped in modifying the soil properties and boosted the soil health.

4.1.4 Number of spines/areoles

Perusal of the data in table 4.2 showed that application of different sources of nitrogen did not reveal any significant difference on the number of spines in dragon fruit cladode in both the years. Maximum number of spines per areole (4.67) was observed in treatment N_{100g}/plant (T_2) in the year 2021 and minimum (3.33) in N_{150g} /plant (T_4) and 75% of N_{125g}+$FYM_{1.25\ kg}$/plant (T_6), whereas maximum number of spines (5.00) were observed in treatment N_{150g} /plant (T_4) in the year 2022.

The pooled data for two years revealed that the maximum number of spines (4.16) were recorded in treatment N_{150g}/plant (T_4) and minimum in 75%

of N_{150g}+Pig manure$_{2.5\ kg}$/plant (T_{10}) (3.16). Rawat *et al*. (2022) reported similar results, where number of spines were found statistically non-significant with the different nutrient sources.

4.1.5 Number of areoles/cladode

The data indicated that various nitrogen sources had a significant effect on areole number (Table 4.2). The maximum number of areoles per cladode (65.67 and 92.08) was recorded in the treatment 75% of N_{150g}+Pig manure$_{2.5\ kg}$/plant (T_{10}) the year 2021 and 2022 respectively and the minimum (26.00) was recorded in N_{125g}/plant (T_3) in first year which increased progressively in the next year.

The pooled data for the two consecutive years revealed that the maximum number of areoles (79.32) were recorded in the treatment 75% of N_{150g}+Pig manure$_{2.5\ kg}$/plant (T_{10}) and the minimum (41.45) in N_{125g}/plant (T_3). This might be due to the increase in nitrogen content provided to plants through various sources which resulted in increase in vegetative growth (Sanju *et al.*, 2003).

4.1.6 Distance between areoles (cm)

The critical examination of data in table 4.2 revealed that the distance between areoles had significantly influenced by the application of different sources of nitrogen. During the year 2021 the maximum distance between areoles (3.30 cm) was recorded in 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) and minimum (1.40 cm) in N_{100g}/plant (T_2) whereas during the year 2022 the maximum (3.83 cm) was recorded in the treatment 75% of N_{100g}+Pig manure$_{1.66\ kg}$/plant (T_8) and minimum was recorded in N_0 Control (T_1) (1.93 cm).

The analysed pooled data revealed that the maximum distance between areoles (0.53 cm) was recorded in treatment 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) and minimum (1.71 cm) in N_0 Control (T_1).

4.1.7 Area of areoles (mm^2)

The data pertaining to the area of areoles depicted in table 4.2 revealed that the application of different sources of nitrogen significantly influenced the area of areoles. The maximum area of areoles (0.17 and 0.20 mm^2) in the year 2021 and 2022 was recorded in treatment 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) and minimum (0.06 mm^2) in N_0 control in the first year and in N_{100g}/plant (T_2) in second year (0.08 mm^2).

Pooled analysis of area of areoles showed that the maximum area of areoles (0.18 mm^2) was recorded in treatment 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) and minimum (0.07 mm^2) in N_{100g}/plant (T_2) and N_0 Control (T_1).

The results regarding the number of areoles, distance between areoles and area of areoles showed that the dragon fruit responded well to the application of pig manure when combined with chemical fertilizers. Abo Abo Abo Sedera *et al*. (2009) stated that nitrogen fertilizer when used along with compost had enhanced the vegetative growth. This might also be due to the availability of chemical fertilizers in the initial stages and organic manures in latter stages which might have helped in improving the soil organic matter, total nitrogen and soil carbon (Kumar *et al.*, 2016 and Reza and Jafar, 2007). The least supply of N, P and K in control might have resulted in limited plant growth and development altering photosynthesis and carbohydrate production (Zekri and Obreza, 2003).

4.1.8 Fresh weight of the cladode (g)

Perusal of the data in table 4.3 and Fig 4.1 showed that the application of different sources of nitrogen had significant effect on fresh weight of cladode in both the years. Highest fresh weight (183.21 g and 215.01 g) was observed in the treatment 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) and the lowest (45.66 g and 52.43 g) in N_{150g}/plant (T_4) in both 2021 and 2022 respectively.

Table 4.2 Effect of various nitrogen sources on spines and areole characteristics of dragon fruit

Treatments	No. of spines/areoles			No. of areoles/cladode			Distance between areoles (cm)			Area of areoles (mm^2)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
N_0 Control	4.00	4.00	4.00	42.67	63.99	53.32	1.50	1.93	1.71	0.06	0.09	0.07
N_{100g}/plant	4.67	3.33	4.00	50.33	82.65	66.49	1.40	2.20	1.80	0.07	0.08	0.07
N_{125g}/plant	4.33	2.67	3.50	26.00	56.90	41.45	2.83	2.83	2.83	0.07	0.11	0.08
N_{150g} /plant	3.33	5.00	4.16	31.08	55.62	43.34	2.83	3.40	3.11	0.08	0.11	0.09
75% of N_{100g}+$FYM_{1\ kg}$/plant	3.67	3.67	3.66	35.67	62.61	49.13	3.06	3.23	3.14	0.11	0.14	0.12
75% of N_{125g}+$FYM_{1.25\ kg}$/plant	3.33	3.67	3.50	45.33	78.95	62.14	2.17	2.37	2.26	0.11	0.15	0.13
75% of N_{150g} +$FYM_{1.5\ kg}$/plant	3.67	3.33	3.50	56.33	88.60	72.46	2.00	2.57	2.28	0.12	0.15	0.13
75% of N_{100g}+Pig $manure_{1.66\ kg}$/plant	3.67	3.33	3.50	63.07	72.98	68.02	3.00	3.83	3.41	0.12	0.16	0.14
75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant	4.33	2.67	3.50	54.33	79.67	67.00	3.30	3.77	3.53	0.17	0.20	0.18
75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant	3.67	2.67	3.16	65.67	92.98	79.32	3.10	3.43	3.26	0.15	0.15	0.15
S Em ±	0.38	0.41	0.23	4.57	2.94	2.76	0.35	0.39	0.31	0.01	0.01	0.01
CD at 5%	1.11	1.24	NS	13.69	8.81	8.27	1.07	1.17	0.94	0.05	0.03	0.03

The pooled data for two years revealed that the maximum fresh weight of the cladode (199.11 g) was recorded in 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) and the minimum in N_{150g}/plant (T_4) (49.04 g). This might be due to the application of high doses of manures to the soil which in turn have helped in increase in absorption of water and nutrients and increase the vegetative growth. Similar findings were reported by Nofriandi *et al*. (2021) in *Hylocereus costaricensis.*

4.1.9 <u>Dry weight of the cladode (g)</u>

Data in table 4.3 and Fig 4.1 indicated that the different sources of nitrogen had significantly influenced the dry weight of the dragon fruit cladode. Application of 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) recorded the highest dry weight (5.56 g and 36.81 g) in both 2021 and 2022 respectively. The minimum (5.99 g) was recorded in N_{100g}/plant (T_2) during the first year and in N_{150g}/plant (T_4) (6.53 g) in second year.

The pooled data for two years revealed that the maximum dry weight of the cladode (31.19 g) was recorded in 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) and the minimum was recorded in N_{150g}/plant (T_4) (6.44 g). The results are in close conformity with Nofriandi *et al*. (2021).

4.1.10 <u>Pericarp and perianth length (cm)</u>

The data recorded in table 4.4 and Fig 4.2 revealed that the different sources of nitrogen had significant effect on perianth length but not on pericarp length. The maximum pericarp length (15.61 cm) was recorded in the treatment 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) and minimum (9.23 cm) in N_{125g}/plant (T_3) whereas, the maximum perianth length (16.06 cm) was recorded in 75% of N_{100g}+$FYM_{1.0}$ kg/plant (T_5) and minimum (12.23 cm) in N_{125g}/plant (T_3).

Table 4.3 Influence of various nitrogen sources on fresh and dry weight of dragon fruit cladode

Treatments	Fresh weight of cladode (g)			Dry weight of cladode (g)		
	2021	2022	Pooled	2021	2022	Pooled
N_0 Control	63.00	67.61	65.30	10.10	9.63	9.87
N_{100g}/plant	51.33	55.00	53.16	5.99	6.97	6.48
N_{125g}/plant	61.62	65.10	63.36	9.31	11.52	10.41
N_{150g} /plant	45.66	52.43	49.04	6.38	6.53	6.44
75% of N_{100g}+FYM_{1kg} /plant	55.00	58.36	56.68	7.29	7.11	7.20
75% of N_{125g}+$FYM_{1.25\ kg}$/plant	64.32	73.54	68.93	7.33	8.80	8.06
75% of N_{150g} +$FYM_{1.5\ kg}$ /plant	60.33	65.01	62.67	7.31	7.79	7.55
75% of N_{100g}+Pig $manure_{1.66\ kg}$/plant	49.12	52.47	50.79	8.57	11.64	10.10
75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant	183.21	215.01	199.11	5.56	36.81	31.19
75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant	91.33	139.33	115.33	9.50	12.77	11.13
S Em±	9.54	9.94	9.26	2.92	4.79	03.77
CD at 5%	28.57	29.78	27.72	8.75	14.34	11.29

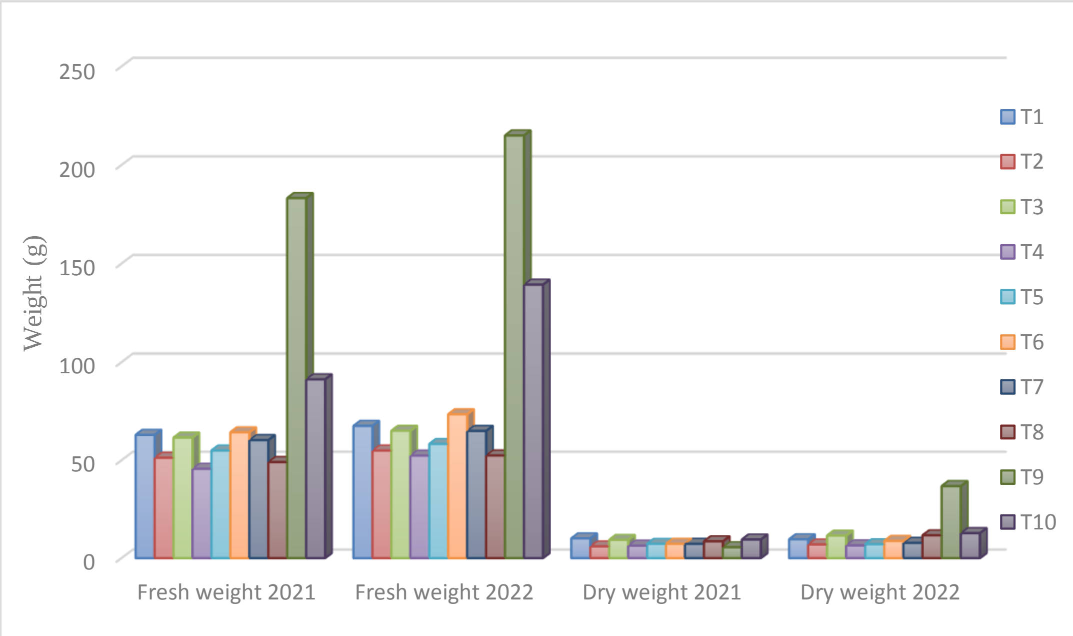


Fig 4.1 Effect of various sources of nitrogen on fresh and dry weight of the cladode

4.1.11 Flower length (cm)

Data on flower length for the year 2022 was presented in the table 4.4 clearly indicated that the various sources of nitrogen had significant effect on length of the flower of dragon fruit during the year 2022. The maximum length (31.07 cm) was noticed in treatment 75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant (T_{10}) which was found at par with 75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant (T_9) (30.09 cm) and minimum (21.26 cm) was recorded in treatment N_{125g}/plant (T_3). The results are in conformity with Ruamrungsri *et al*. (2021) who reported that the flower length increased with the increase in nitrogen doses and found reduced under treatments supplied with less nitrogen. The increase in the flower length might be due to the genetic character of the plant or may be due to the availability of different sources of organic and inorganic fertilizers especially nitrogen which may have raised the various endogenous hormones and boosted the tube development resulting in increase in flower length. Results are in close conformity with Perween and Hasan (2018) in dragon fruit.

4.1.12 Petal length (cm)

A perusal of the data in table 4.4 and Fig 4.2 revealed that the length of the petal was influenced by the application of various sources of nitrogen. The maximum value (19.31 cm) was recorded in the treatment 75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant (T_9) and minimum (12.57 cm) in the treatment 75% of N_{150g}+ $FYM_{1.5\ kg}$ /plant (T_7).

4.1.13 Petal number

The data presented in table 4.4 revealed that the highest petal number (27.00) was recorded in the treatment N_0 Control (T_1) and lowest (18.66) in 75% of N_{150g}+$FYM_{1.5\ kg}$/plant (T_7).

Table 4.4 Effect of various nitrogen sources on flower characteristics of dragon fruit

Treatments	Pericarp length (cm)	Perianth length(cm)	Flower length (cm)	Petal length (cm)	Petal number
N_0 Control	13.70	12.80	25.72	16.05	27.00
N_{100g}/plant	13.16	13.53	26.93	15.71	24.00
N_{125g}/plant	9.23	12.23	21.26	15.82	22.33
N_{150g} /plant	9.83	13.80	23.93	14.83	19.00
75% of N_{100g}+$FYM_{1\ kg}$/plant	14.66	16.06	30.69	18.05	21.66
75% of N_{125g}+$FYM_{1.25\ kg}$/plant	13.66	14.10	26.41	16.50	24.33
75% of N_{150g} +$FYM_{1.5\ kg}$/plant	11.33	13.76	24.29	12.57	18.66
75% of N_{100g}+Pig $manure_{1.66\ kg}$/plant	13.50	14.06	27.56	16.66	21.00
75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant	15.61	15.50	31.01	19.31	20.66
75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant	15.50	15.83	31.07	17.95	19.00
S Em±	1.19	0.96	2.03	0.88	2.23
CD at 5%	3.57	NS	6.10	2.64	6.47

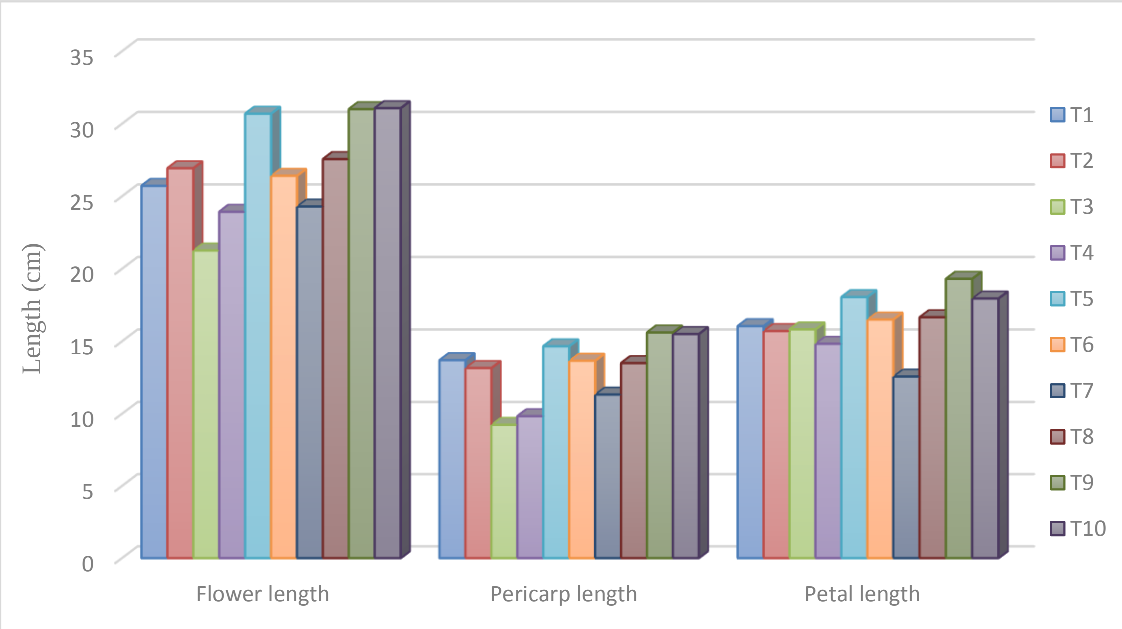


Fig 4.2 Effect of various sources of nitrogen on flower, petal and pericarp length

4.1.14 Style length (cm)

It is evident from the data presented in table 4.5 and Fig 4.3 that the different sources of nitrogen had no significant effect on style length. Highest style length (14.96 cm) was recorded in the treatment 75% of N_{125g}+$FYM_{1.25\ kg}$/plant (T_6) and lowest (11.13 cm) in N_{125g}/plant (T_3).

4.1.15 Stamen length (cm)

The data recorded on stamen length was presented in table 4.5 and Fig 4.3 and was found significantly influenced by the different sources of nitrogen. The maximum stamen length (12.42 cm) was recorded in the treatment 75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant (T_{10}) and minimum (8.00 cm) in N_{125g}/plant (T_3).

4.1.16 Distance between stigma to anther (cm)

The data depicted in table 4.5 showed that the different sources of nitrogen had no significant effect on distance between stigma to anther (Table 4.5). Among all the treatments, maximum distance (1.93 cm) was observed in the treatment 75% of N_{150g}+$FYM_{1.5\ kg}$/plant (T_7) and minimum (0.20 cm) was observed in 75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant (T_9).

The significant effect of nitrogen on flower parameters might be due to the genetic character of dragon fruit plant or may be due to the manures and fertilizers applied during the growth period, as nitrogen and phosphorous plays major role in plant metabolic process resulting in improving the flowering and fruiting. Sharma *et al.* (2019) reported that the application of organic manures either alone or in combination with inorganic fertilizers might have resulted in the increase of soil NPK and other micronutrients improving plant health by supplying adequate nutrition to plant resulting in good flowering and fruiting.

4.1.17 Stigma lobe length (cm)

There is no significant variation found in the stigma lobe length by different sources of nitrogen. The maximum lobe length (2.40 cm) was recorded in the treatment 75% of N_{100g}+Pig $manure_{1.66\ kg}$/plant (T_8) and 75 % of

Table 4.5 Effect of various nitrogen sources on reproductive flower characteristics of dragon fruit

Treatments	Style length (cm)	Stamen length (cm)	Distance between Stigma to anther (cm)	Stigma lobe length (cm)	Number of stigma lobes
N_0 Control	14.28	11.17	0.56	1.73	27.00
N_{100g}/plant	12.81	10.50	1.60	1.70	27.66
N_{125g}/plant	11.13	8.00	1.66	1.86	26.00
N_{150g} /plant	13.49	9.00	1.46	2.20	24.66
75% of N_{100g}+FYM_{1kg}/plant	14.26	11.54	0.80	2.10	30.66
75% of N_{125g}+$FYM_{1.25\ kg}$/plant	14.96	11.86	1.30	1.93	32.33
75% of N_{150g} +$FYM_{1.5\ kg}$/plant	13.02	9.16	1.93	2.06	27.33
75% of N_{100g}+Pig $manure_{1.66kg}$/plant	12.16	10.16	0.33	2.40	30.00
75% of N_{125g}+Pig $manure_{2.1kg}$/plant	12.34	10.63	0.20	2.40	31.33
75% of N_{150g}+Pig $manure_{2.5kg}$/plant	14.95	12.42	0.80	2.00	24.33
S Em±	0.90	0.76	0.54	0.30	1.77
CD at 5%	NS	2.28	NS	NS	5.13

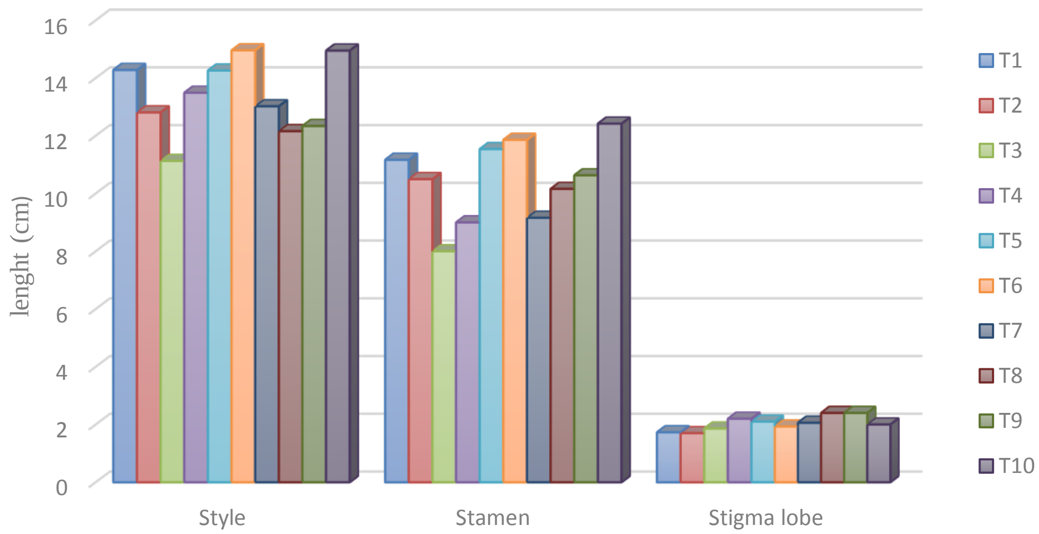


Fig 4.3 Effect of various sources of nitrogen on style, stamen and stigma lobe length

N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) and minimum (1.70 cm) in N_{100g}/plant (T_2) (Table 4.5 and Fig 4.3).

4.1.18 Number of stigma lobes

Different sources of nitrogen had significant effect on number of stigma lobes (Table 4.5). The highest lobes (32.33) were recorded in the treatment 75% of N_{125g}+FYM$_{1.25\ kg}$/plant (T_6) and lowest (24.33) in 75% of N_{150g}+Pig manure $_{2.5\ kg}$/plant (T_{10}).

4.1.19 Fruit size (cm)

The data presented in table 4.6 clearly revealed that the fruit length and width differed significantly due to the various sources of nitrogen. The highest fruit length (8.50 cm) and width (8.36 cm) were observed with treatment 75% of N_{150g}+Pig manure$_{2.5\ kg}$/plant (T_{10}) which was found statistically at par with 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) (8.53 cm and 8.26 cm) whereas the lowest fruit length (6.43 cm) and width (6.91 cm) were recorded in the treatment N_{150g} /plant (T_4).Treatments N_0 Control (T_1), N_{100g}/plant (T_2) and N_{150g}/plant (T_4) didn't showed any fruits during the experimental period (2021 and 2022). Pig manure in combination with chemical fertilizers recorded more length and breadth when compared to vermicompost and other organic manures (Dey *et al*., 2022). The increase in length and breadth might be due to the availability of more nitrogen (supplied through pig manure and chemical fertilizer) which might have led to the increase in chlorophyll content of cladodes resulting in more photosynthesis and enhancing the metabolic activities in plant which led to high carbohydrate and protein synthesis thus increasing length and breadth (Ahmad and Mohammad, 2012).

4.1.20 Number of fruits/pillar

A perusal of the data in table 4.6 revealed that the number of fruits per pillar was influenced by the application of various sources of nitrogen. The highest number of fruits (20.00) was recorded in the treatment 75% of

N_{150g}+Pig manure$_{2.5\ kg}$/plant (T_{10}) and treatments N_0 Control, N_{100g}/ plant and N_{125g}/plant recorded no fruits. The increase in number of fruits might be due to the application of higher dose of fertilizers which might have promoted more fruits compared to other treatments and also there was an increasing trend in number of fruits by increase in fertilizer doses whereas the lowest treatments with no fruits might be due to the application of less fertilizer which might have resulted in less vegetative growth further leading to no fruits.

4.1.20 Fruit weight (g)

Significant variation was observed in the average fruit weight and the data was represented in the table 4.6. Application of different sources of nitrogen resulted in increase in the average fruit weight. The maximum average fruit weight (401.25 g) was recorded in the treatment 75% of N_{150g}+Pig manure$_{2.5\ kg}$ /plant (T_{10}) supplied with highest dose of pig manure which was statistically at par with 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) (395.42 g) and the minimum (182.33 g) was recorded in N_{150g} /plant (T_4). Results are in close conformity with Awosika *et al.* (2014) where combined use of pig manure and chemical fertilizer in tomato gave highest fruit weight. Application of nitrogen through various sources might have resulted in cell division and elongation and further leading to increase in fruit weight (Nehra *et al.,* 1982 and Mu *et al*., 2017).

4.1.21 Pulp weight (g)

It is evident from the data presented in table 4.6 and Fig 4.4 that the pulp weight varied significantly with the application of different sources of nitrogen. The data revealed that the maximum pulp weight (304.33 g) was recorded in treatment 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) which was found statistically at par with 75% of N_{150g}+Pig manure$_{2.5\ kg}$/plant (T_{10}) (301.00 g) and minimum (119.33 g) in N_{150g}/plant (T_4).Application of organic manures along with chemical fertilizers might have resulted in increase of vegetative growth of plant which resulted in production of more

Table 4.6 Effect of various nitrogen sources on fruit characteristics of dragon fruit

Treatments	Fruit weight (g)	Number of fruits/pillar	Fruit length (cm)	Fruit width (cm)	Pulp weight (g)	Peel weight (g)	Peel thickness (mm)
N_0 Control	-	-	-	-	-	-	-
N_{100g}/plant	-	-	-	-	-	-	-
N_{125g}/plant	-	-	-	-	-	-	-
N_{150g} /plant	182.33	5.00	6.43	6.91	119.33	63.66	3.82
75% of N_{100g}+$FYM_{1\ kg}$/plant	309.66	10.33	7.27	7.21	239.66	73.00	4.85
75% of N_{125g}+$FYM_{1.25\ kg}$/plant	283.66	9.00	7.12	6.93	219.66	68.33	5.24
75% of N_{150g} +$FYM_{1.5\ kg}$/plant	324.00	11.00	7.98	7.70	240.54	84.62	2.04
75% of N_{100g}+Pig $manure_{1.66\ kg}$/plant	340.21	17.00	8.43	8.20	261.58	79.54	2.67
75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant	395.42	16.66	8.35	8.26	304.33	89.36	3.03
75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant	401.25	20.00	8.50	8.36	301.00	100.21	2.32
S Em±	41.84	0.99	0.21	0.22	36.10	8.63	0.40
CD at 5%	125.28	2.98	0.63	0.67	108.10	25.85	1.22

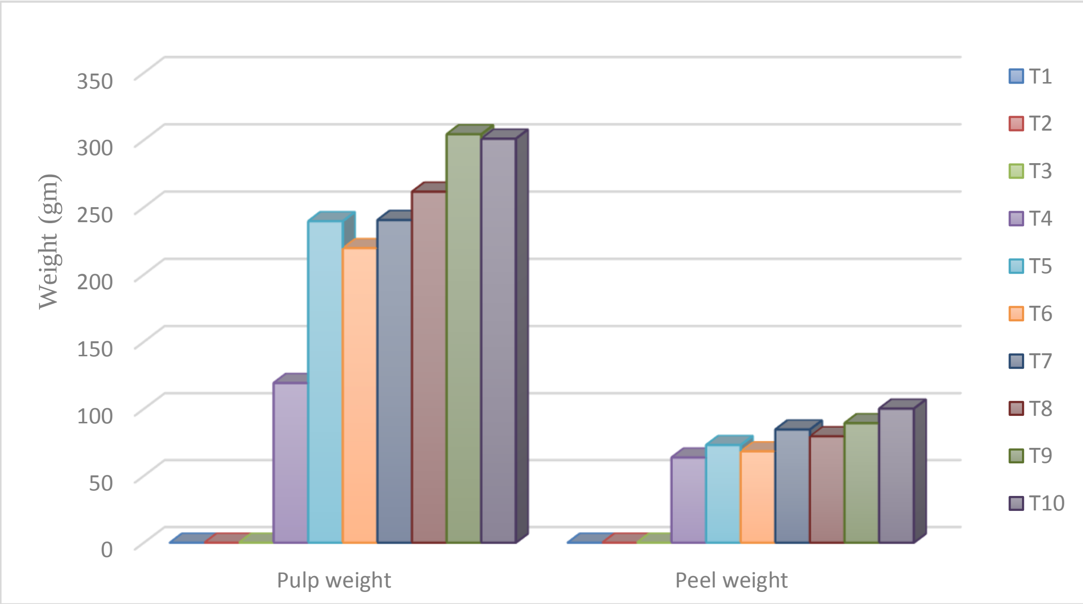


Fig 4.4 Effect of various sources of nitrogen on pulp and peel weight of dragon fruit

photosynthates leading to record high fruit weight which in turn resulted in high pulp weight (Shivakumar, 2012).

4.1.22 Peel weight (g)

A perusal of the data in table 4.6 and Fig 4.4 revealed that the peel weight was influenced by the application of various sources of nitrogen. The maximum peel weight (100.21 g) was recorded in the treatment 75% of N_{150g}+Pig manure$_{2.5\ kg}$/plant (T_{10}) and was at par with treatment 75% of N_{125g}+Pig manure$_{2.1\ kg}$/plant (T_9) (89.36 g). The minimum peel weight (63.66 g) was recorded in the treatment N_{150g}/plant (T_4). The increase in the peel weight might be due to the better nutrient supply which might have caused the rapid cell division and fruit enlargement during the growth and maturation period of fruit (Agarwal *et al.*, 1997).

4.1.23 Peel thickness (mm)

The data in table 4.6 indicated that various nitrogen sources had a significant effect on peel thickness. The maximum peel thickness (5.24 mm) was recorded in the treatment 75% of N_{125g}+FYM$_{1.25\ kg}$/plant (T_6) which was found statistically at par with 75% of N_{100g}+FYM$_{1\ kg}$/plant (T_5) (4.85 mm) and the minimum peel thickness (2.04 mm) was recorded in T_7 75% of N_{150g}+FYM$_{1.5\ kg}$/plant (T_7).

4.1.24 TSS (°Brix)

Data in table 4.7 indicated that the different sources of nitrogen had significantly influenced the TSS of the dragon fruit. Maximum TSS was recorded highest (15.46°Brix) in the treatment 75% of N_{100g}+Pig manure$_{1.66\ kg}$/plant (T_8) which was found statistically at par with treatment 75% of N_{150g}+Pig manure$_{2.5\ kg}$/plant (T_{10}) (15.33°Brix) and minimum (11.66°Brix) was recorded in N_{150g} /plant (T_4). Similar results were reported by Pandey (2023).

The increase in the TSS might be due to the degradation of polysaccharides as the fruits matured (Salunkhe *et al.*, 1974) or may be due to the synergistic effect of using different organic and inorganic manures (Hamid *et al.,* 2006). The results are in contradiction to the studies conducted by Herrero *et al*. (2001) and Krusekopf *et al*. (2022) who reported that soluble solids are not affected by nitrogen fertilization. Nitrogen plays an important role in enhancing the fruit quality. The increase in the TSS and sugar content might be due to the transfer of carbohydrates from roots and stem to fruits during the ripening process (Antipchuk *et al.,* 1982).

4.1.25 Titratable acidity (%)

Significant variation was observed in the titratable acidity and the data was represented in the table 4.7. The maximum acidity (0.25%) was recorded in the treatment 75% of N_{100g}+$FYM_{1.0kg}$/plant (T_5) and the minimum (0.13%) were recorded in 75% of N_{150g}+$FYM_{1.5kg}$/plant (T_7) and 75% of N_{150g}+Pig $manure_{2.5kg}$/plant (T_{10}). The variation in the quality parameters might be due to the genetic characteristics, environmental conditions and type of manures used. Results were similar to the findings of Olaniyi and Ajibola (2008) in tomato.

4.1.26 Reducing sugars (%)

A perusal of the data in table 4.7 and Fig 4.7 revealed that the reducing sugars was influenced by the application of various sources of nitrogen. The maximum reducing sugar content (7.55%) was recorded in the treatment 75% of N_{150g}+$FYM_{1.5kg}$/plant (T_7) which was found statistically at par with 75% of N_{100g}+Pig $manure_{1.66kg}$/plant (T_8) (6.84%) and minimum (5.48%) in the treatment N_{150g}/plant (T_4). The combination of FYM and inorganic fertilizers might have increased the micro and macro nutrients present in the soil which played a better role in carbohydrate synthesis promoting the reducing sugars in fruit (Rahman *et al.* 2021).

4.1.27 Total sugars (%)

Observations recorded on total sugars were summarized in table 4.7 and Fig 4.5. The data revealed that the application of different sources of nitrogen significantly influenced the total sugars. Maximum total sugars (9.49%) were

Table 4.7 Effect of various nitrogen sources on biochemical parameters of dragon fruit

Treatments	TSS (°Brix)	Titratable acidity (%)	Reducing Sugars (%)	Total Sugars (%)	Ascorbic acid (mg/100g)
N_0 Control	-	-	-	-	-
N_{100g}/ plant	-	-	-	-	-
N_{125g}/plant	-	-	-	-	-
N_{150g} /plant	11.66	0.15	5.48	6.78	2.61
75% of N_{100g}+ FYM $_{1\ kg}$ /plant	12.81	0.25	4.89	7.20	2.41
75% of N_{125g}+FYM $_{1.25\ kg}$/plant	13.36	0.15	5.94	6.54	3.36
75% of N_{150g} + FYM $_{1.5\ kg}$ /plant	13.20	0.13	7.55	9.49	2.80
75% of N_{100g}+ Pig manure $_{1.66\ kg}$/plant	15.46	0.14	6.84	8.88	2.99
75% of N_{125g}+ Pig manure $_{2.1\ kg}$/plant	14.63	0.10	6.34	7.19	2.80
75% of N_{150g}+ Pig manure $_{2.5\ kg}$/plant	15.33	0.13	5.96	8.68	3.17
S Em±	0.48	0.02	0.28	0.41	0.39
CD at 5%	1.44	0.07	0.85	1.25	1.18

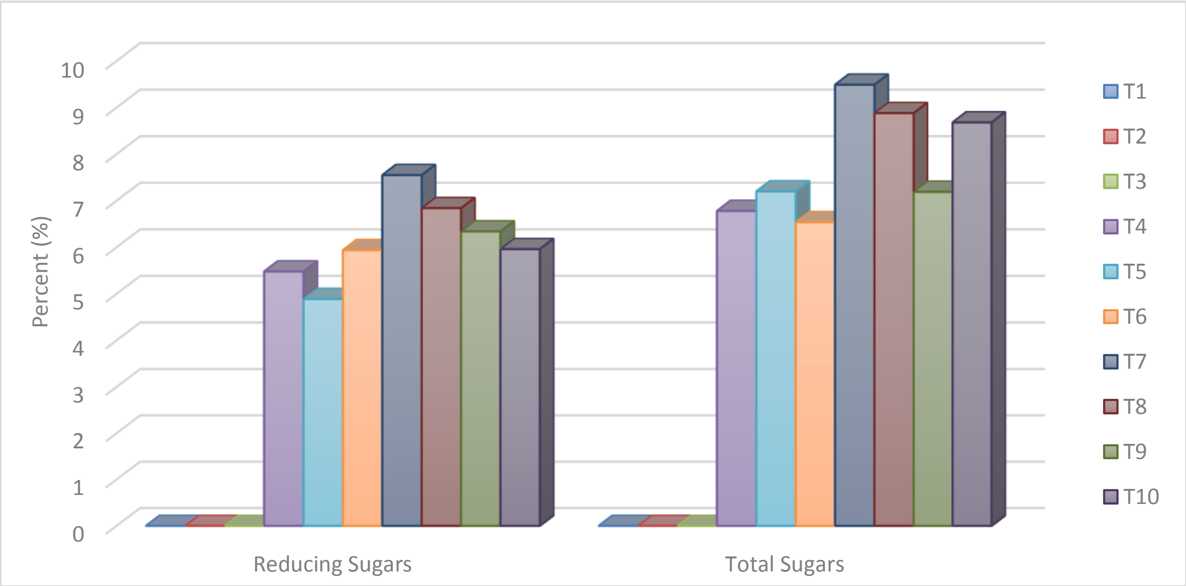


Fig 4.5 Effect of various sources of nitrogen on reducing and total sugars of dragon fruit

observed in the treatment supplied with the fertilizers dose of 75% of N_{150g}+$FYM_{1.5kg}$/plant (T_7) which was found statistically at par with treatment 75% of N_{100g}+Pig $manure_{1.66\ kg}$/plant (T_8) (8.88%). The minimum (6.54%) was recorded in the treatment 75% of N_{125g}+$FYM_{1.25\ kg}$/plant (T_6). This might be due to the conversion of starch into sugars (Moneruzzaman *et al*., 2009).

4.1.28 Ascorbic acid (mg/100g)

The data recorded in table 4.7 showed that the ascorbic acid content was significantly influenced by the different sources of nitrogen. The maximum ascorbic acid content (3.36 mg/100g) was recorded in the treatment 75% of N_{125g}+$FYM_{1.25kg}$/plant (T_6), it was found statistically at par with 75% of N_{150g}+ Pig $manure_{2.5kg}$/plant (T_{10}) (3.17 mg/100g) and minimum (2.41 mg/100g) in N_{150g} /plant (T_4). The vitamin C levels in fruits and vegetables can be influenced by various factors, including climatic conditions, cultural practices, and genotypic differences (Mozafar, 1993; Weston and Barth, 1997; Taha *et al*., 2014). Ascorbic acid recorded lowest compared to other studies which might be due to the high nitrogen supply leading to increase in vegetative growth resulting in less light intensity and production of vitamin-C content (Mozafar, 1993).

4.1.29 Peel phenolic content (mg GAE/100g)

Table 4.8 and Fig 4.6 clearly revealed that the phenolic content of peel was significantly influenced by the different nitrogen sources. The maximum phenolic content in peel (53.97 mg GAE/100g) was recorded in N_{150g}/plant (T_4) and lowest (37.14 mg GAE/100g) in 75% of N_{150g}+$FYM_{1.5kg}$/plant (T_7).

4.1.30 Pulp phenolic content (mg GAE /100g)

Data on phenolic content in pulp of dragon fruit is summarized in table 4.8 and Fig 4.6 and revealed that the maximum pulp phenolic content (57.08 mg GAE/100g) was recorded in the treatment 75% of N_{150g}+Pig $manure_{2.5kg}$/plant (T_{10}). The minimum pulp phenolic content (36.26 mg GAE/100g) was recorded in the treatment 75% of N_{125g}+$FYM_{1.25\ kg}$/plant (T_6).

Table 4.8 Effect of various nitrogen sources on quality parameters of dragon fruit

Treatments	Peel phenolic content (mg GAE/100g)	Pulp phenolic content (mg GAE/100g)	Peel betacyanin content (mg/100g)	Pulp betacyanin content (mg/100g)
N_0 Control	-	-	-	-
N_{100g}/ plant	-	-	-	-
N_{125g}/plant	-	-	-	-
N_{150g} /plant	53.97	37.93	34.31	37.33
75% of N_{100g}+ FYM $_{1\ kg}$ /plant	43.43	40.39	38.90	39.97
75% of N_{125g}+FYM $_{1.25\ kg}$/plant	40.24	36.26	51.22	56.36
75% of N_{150g} + FYM $_{1.5\ kg}$ /plant	37.14	48.17	36.25	32.63
75% of N_{100g}+ Pig manure $_{1.66\ kg}$/plant	44.40	55.32	39.59	34.98
75% of N_{125g}+ Pig manure $_{2.1\ kg}$/plant	51.15	48.78	32.48	39.50
75% of N_{150g}+ Pig manure $_{2.5\ kg}$/plant	47.03	57.08	45.61	47.50
S Em±	4.22	2.79	1.44	1.02
CD at 5%	12.65	8.37	4.31	3.06

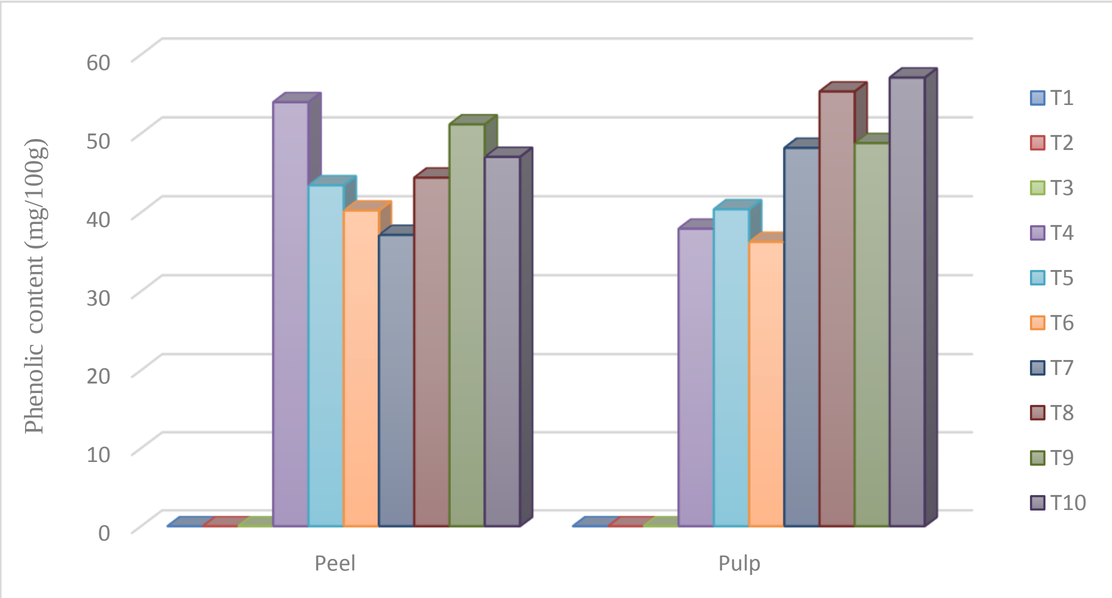


Fig 4.6 Effect of various sources of nitrogen on peel and pulp phenol content of dragon fruit

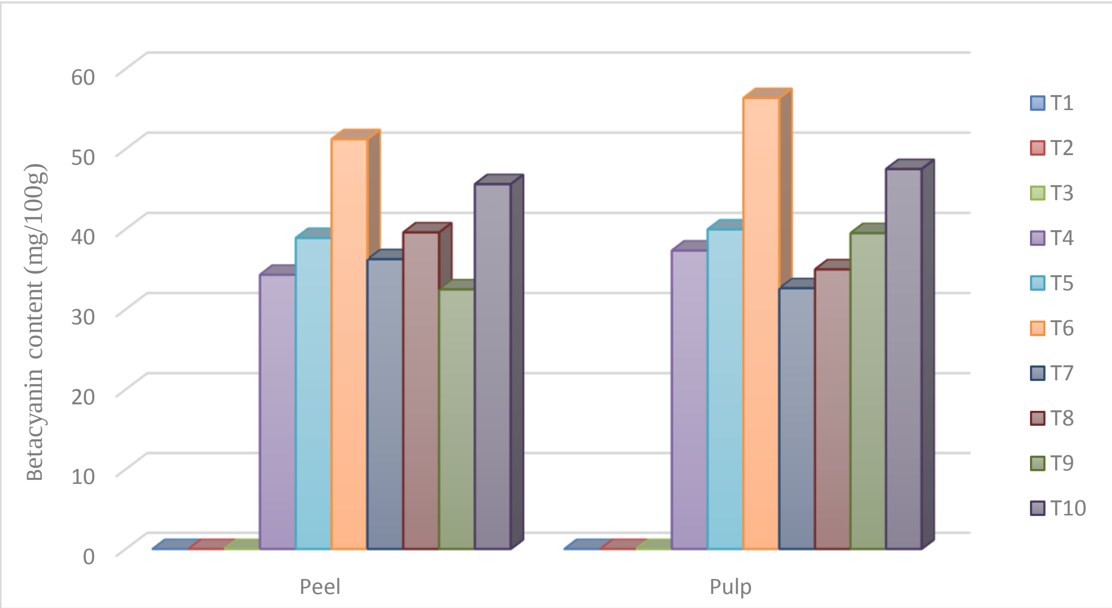


Fig 4.7 Effect of various sources of nitrogen on peel and pulp betacyanin content of dragon fruit

4.1.31 Peel betacyanin content (mg/100g of fresh weight)

Perusal of the data presented in table 4.8 and Fig 4.7 revealed that there were significant differences among the treatments with respect to peel betacyanin content. Highest betacyanin content in peel (51.22 mg/100g) was observed in the treatment 75% of N_{125g}+$FYM_{1.25\ kg}$/plant (T_6) and lowest (32.48 mg/100g) in 75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant (T_9).

4.1.32 Pulp betacyanin content (mg/100g of fresh weight)

Betacyanin content in the pulp of dragon fruit varied significantly with the different sources of nitrogen as depicted in table 4.8 and Fig 4.7. The maximum betacyanin content in pulp (56.36 mg/100g) was observed in 75% of N_{125g}+$FYM_{1.25\ kg}$/plant (T_6) whereas minimum (32.63 mg/100g) was recorded in 75% of N_{150g}+$FYM_{1.5\ kg}$/plant (T_7). The treatments with high doses of nitrogen recorded low concentrations of betacyanin (Tanaka *et al.,* 2008). The results are in close conformity with Sitompul and Zulfati (2019) and Pangestika *et al*. (2021) who reported that the application of high doses of nitrogenous fertilizers had decreased the betacyanin content in beet root.

The quality of fruits might have increased due to the application of organic manures with balanced fertilizers. Similar results were reported by Lai *et al.* (2011) in Kiwi and Zhao *et al*. (2013) also reported that organic manures might have improved the fruit quality like ascorbic acid and soluble sugars in Apple. There is also a possibility that the increase in plant vegetative growth under organic treatments contributed to the improved fruit quality. This might be due to the higher levels of photosynthates transported into the fruits, thus increasing various parameters linked to fruit quality (Jaiswal *et al*. 2023).

4.1.33 Available soil Nitrogen (kg ha^{-1})

A perusal of data presented in table 4.9 revealed that the different sources of nitrogen marked significant influence on the available N in the soil during both the years of study. The average available nitrogen ranged between 399.38 to 334.08 kg ha^{-1} in 2021and 387.31 to 290.32 kg ha^{-1} in 2022 among the different treatments. The pooled analysis revealed that the highest (393.35 kg ha^{-1}) available N was recorded in 75% of N_{150g}+Pig $manure_{2.5kg}$/plant (T_{10}) which was significantly higher than all other treatments. It was found statistically at par with treatment 75% of N_{125g}+Pig $manure_{2.1kg}$/plant (T_9) recording 390.64 kg ha^{-1}, whereas, the lowest (312.20 kg ha^{-1}) was recorded in N_0 Control (T_1). The results were in close conformity with Giwa and Ojeneyi (2004) who reported that the combined application of pig manure with inorganic fertilizers (N, P and K) increased the available soil nitrogen in tomato. Khandagle *et al.* (2019) ; Chahal *et al*. (2019) and Arbad and Ismail (2014) also reported that integrated application of organic and inorganic manures increased the soil available nitrogen.

4.1.34 Available soil phosphorus (kg ha^{-1})

The data presented in table 4.9 showed that different sources of nitrogen had significant influence on available soil phosphorus during both the years. During the year 2021 the results revealed that the maximum available phosphorus in the soil was recorded (42.32 kg ha^{-1}) with the treatment 75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant (T_{10}), whereas minimum was recorded under N_0 Control (T_1) (26.35 kg ha^{-1}). Similarly, in the year 2022 the maximum available phosphorus content in the soil was recorded (40.60 kg ha^{-1}) with the treatment 75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant (T_{10}), while minimum was recorded under N_0 Control (T_1) (23.68 kg ha^{-1}). The pooled analysis revealed that, the highest 41.46 kg ha^{-1} available P was recorded in 75% of N_{150g}+Pig $manure_{2.5kg}$/plant (T_{10}) which was found statistically at par with treatment 75% of N_{125g}+Pig $manure_{2.1kg}$/plant (T_9) recording 40.42 kg ha^{-1}, whereas, the lowest (25.02 kg ha^{-1}) was recorded in N_0 Control (T_1).

This might be due to the solubilisation of phosphorous by organic acids produced during the decomposition of organic matter which might have chelated the cations thereby increasing the phosphorous availability to the

Table 4.9 Impact of nitrogen sources on available NPK (kg ha^{-1}) in soil

Treatments	Available soil nitrogen (kg ha^{-1})			Available soil phosphorous (kg ha^{-1})			Available soil potassium (kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
N_0 Control	334.08	290.32	312.20	26.35	23.68	25.02	187.35	179.33	183.34
N_{100g}/ plant	371.62	328.27	349.95	29.99	26.31	28.15	183.35	174.66	179.00
N_{125g}/plant	377.99	339.56	358.77	32.32	29.97	31.14	177.60	164.33	170.96
N_{150g} /plant	378.13	342.42	360.27	34.32	31.58	32.95	188.66	182.68	185.67
75% of N_{100g}+ $FYM_{1\ kg}$ /plant	374.45	348.64	361.54	34.65	32.68	33.66	208.33	197.67	203.00
75% of N_{125g}+$FYM_{1.25\ kg}$/plant	373.47	353.84	363.65	35.29	33.38	34.34	226.95	220.73	223.84
75% of N_{150g} + $FYM_{1.5\ kg}$ /plant	380.49	361.69	371.09	40.65	37.69	39.17	236.98	228.33	232.65
75% of N_{100g}+ Pig manure $_{1.66\ kg}$/plant	383.82	368.05	375.93	40.66	39.27	39.97	196.75	192.32	194.53
75% of N_{125g}+ Pig manure $_{2.1\ kg}$/plant	396.67	384.61	390.64	41.54	39.30	40.42	216.98	212.97	214.97
75% of N_{150g}+ Pig manure $_{2.5\ kg}$/plant	399.38	387.31	393.35	42.32	40.60	41.46	223.01	218.63	220.82
S Em±	11.01	11.43	8.65	1.38	2.14	1.49	4.70	5.26	3.06
CD at 5%	32.96	34.24	25.92	4.14	6.41	4.48	14.09	15.76	9.17

plants. Singh *et al*. (2015) reported that the integrated use of organic and inorganic manures increased the phosphorous content in soil. The use of phosphorous solubilising bacteria (PSB) might have converted the insoluble form of phosphorous in to soluble form thus making it available to the plants hence fostering development (Chandler *et al.,* 2008).

4.1.35 Available soil potassium (kg ha^{-1})

It is evident from the data summarized in table 4.9 that the available K content in the soil for the year 2021 was maximum (236.98 kg ha^{-1}) in the treatment 75% of N_{150g}+$FYM_{1.5kg}$/plant (T_7) which was significantly superior over rest of the treatments and the minimum available soil potassium (183.35 kg ha^{-1}) was recorded in the treatment N_0 Control (T_1). Similarly in the year 2022, the maximum available potassium content in the soil was recorded (228.33 kg ha^{-1}) with the treatment 75% of N_{150g}+$FYM_{1.5kg}$/plant (T_7) which was found at par with treatment 75% of N_{125g}+$FYM_{1.25\ kg}$/plant (T_6) (220.73 kg ha^{-1}), while minimum available soil potassium was recorded under N_0 Control (T_1) (164.33 kg ha^{-1}).The pooled analysis revealed that the highest (232.65 kg ha^{-1}) available K was recorded in 75% of N_{150g}+$FYM_{1.5kg}$/plant (T_7) which was significantly higher than all other treatments and was found statistically at par with treatment 75% of N_{125g}+$FYM_{1.25\ kg}$/plant recording (T_6) 223.84 kg ha^{-1}, whereas, the lowest (170.96 kg ha^{-1}) was recorded in N_0 Control (T_1). The combination of organic and inorganic fertilizers might have resulted in increase of available soil N, P and K (Arbad and Ismail, 2014). The addition of organic manures in soil might have resulted in increase of H^+ ions in the soil which might have further improved the cation exchange capacity thus resulting in availability of N, P and K.

4.1.36 Nitrogen (%)

The data pertaining to nitrogen content in cladodes was influenced by various sources of nitrogen is presented in table 4.10 and graphically depicted in Fig 4.8. The highest nitrogen uptake by plants in the year 2021 and 2022

Table 4.10 Impact of nitrogen sources on NPK (%) in dragon fruit cladodes

Treatments	Nitrogen (%)			Phosphorous (%)			Potassium (%)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
N_0 Control	0.34	0.79	0.57	0.25	0.21	0.23	2.82	3.05	2.94
N_{100g}/ plant	1.11	1.49	1.30	0.44	0.39	0.42	3.95	4.16	4.06
N_{125g}/plant	1.45	1.73	1.59	0.26	0.29	0.28	6.21	6.92	6.57
N_{150g} /plant	1.42	1.54	1.48	0.16	0.18	0.17	4.23	4.50	4.37
75% of N_{100g}+ FYM_{1kg}/plant	2.10	1.17	1.64	0.20	0.23	0.21	5.93	6.48	6.21
75% of N_{125g}+$FYM_{1.25\ kg}$/plant	1.84	2.24	2.04	0.26	0.25	0.26	4.10	4.41	4.26
75% of N_{150g} +$FYM_{1.5\ kg}$/plant	1.78	1.91	1.85	0.16	0.18	0.17	5.21	6.47	5.84
75% of N_{100g}+Pig $manure_{1.66\ kg}$/plant	1.84	1.03	1.43	0.35	0.36	0.35	4.54	5.99	5.27
75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant	2.73	1.91	2.32	0.56	0.59	0.58	9.31	10.14	9.73
75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant	2.82	2.80	2.81	0.53	0.51	0.52	9.21	9.79	9.50
S Em±	0.22	0.42	0.23	0.07	0.01	0.03	0.42	0.73	0.39
CD at 5%	0.66	1.20	0.69	0.22	0.05	0.11	1.26	2.18	1.19

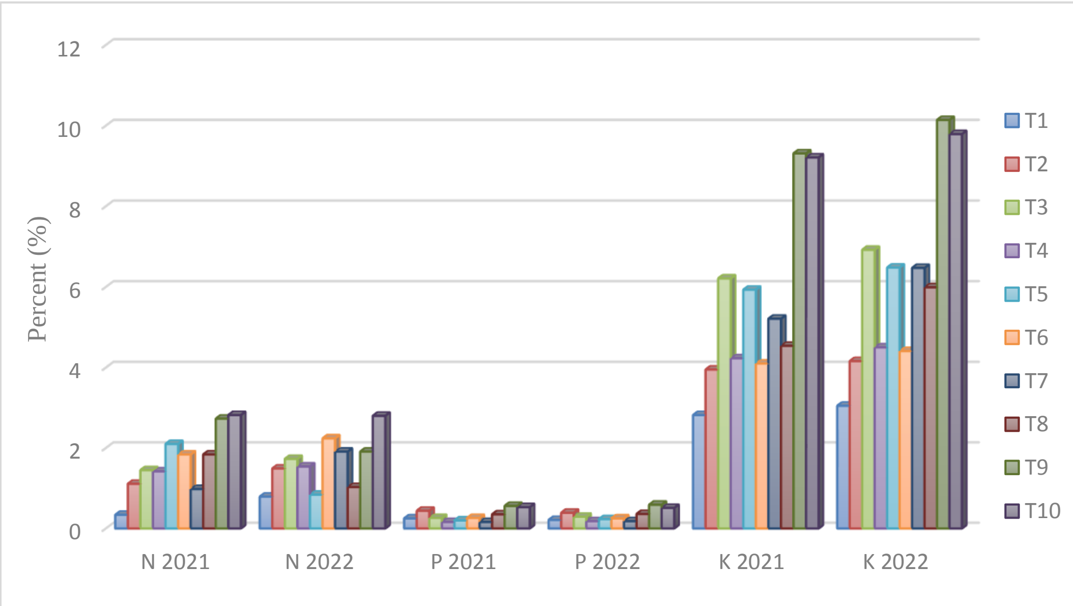


Fig 4.8 Impact of nitrogen sources on plant NPK (%) of cladodes

(2.82 and 2.80%) was recorded in the treatment 75% of N_{150g}+Pig manure$_{2.5kg}$/plant (T_{10}) whereas the minimum (0.34 and 0.79%) was recorded in the treatment N_0 Control (T_1). The pooled analysis revealed that the maximum nitrogen uptake by plants (2.81%) was recorded in the treatment 75% of N_{150g}+Pig manure$_{2.5kg}$ /plant (T_{10}) which was found statistically at par with 75% of N_{125g}+Pig manure 2.1kg/plant (T_9) (2.32%) and minimum (0.57%) in N_0 Control (T_1). The pig manure used in combination with NPK might have increased the plant nitrogen content. Similar results were reported by Giwa and Ojeneyi (2004) in tomato leaf. Pig manure being a rich source of organic manure might have increased the mineralization and due to its low C: N ratio compared to other organic manures might have resulted in faster decomposition thus making the nutrients available to the plant (Ano and Ubochi, 2007).

4.1.37 Phosphorus (%)

It is apparent from the data presented in the table 4.10 and Fig 4.8 that during 2021-2022, the highest phosphorous uptake (0.56 and 0.59%) was observed in 75% of N_{125g}+Pig manure$_{2.1kg}$/plant (T_9), while the lowest (0.16 and 0.18%) was recorded in N_{150g}/plant and 75% of N_{150g}+FYM$_{1.5kg}$/plant (T_7). The analysis of pooled data revealed that the maximum phosphorous uptake (0.58%) was recorded with 75% of N_{125g}+Pig manure$_{2.1kg}$/plant (T_9), which was significantly higher than all other treatments and was found statistically at par with treatment 75% of N_{150g}+Pig manure$_{2.5kg}$/plant (T_{10}) (0.52%). While, minimum (0.17%) was observed in treatments N_{150g}/plant and 75% of N_{150g}+ FYM$_{1.5kg}$/plant (T_7). This might be due to the application of phosphorous solubilizing bacterial to soil which solubilized unavailable form of phosphorous in to available form to the plant (Singh *et al*., 2003).

4.1.38 Potassium (%)

It is evident from the table 4.10 and Fig 4.8 that the potassium uptake by plant had differed significantly among the treatments during both the years of investigation. The highest (9.31 and 10.14%) was observed in the treatment 75% of N_{125g}+Pig $manure_{2.1kg}$/plant (T_9) while the lowest (2.82 and 3.05%) was observed in N_0 Control (T_1) during 2021 and 2022 respectively. The pooled data revealed that the highest (9.73%) was found in treatment 75% of N_{125g}+Pig $manure_{2.1\ kg}$/plant (T_9) which was found at par with treatment 75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant (T_{10}) (9.50%). Among all the treatments, the lowest (2.94%) was recorded in N_0 Control (T_1). Ahmad *et al*. (2004) reported similar results in Guava. The integrated use of organic, inorganic and bio fertilizers might have resulted in surge of potassium content in leaf by improving the soil health which resulted in better rooting, making the better uptake of potassium.

4.2 Phenology of dragon fruit

Data pertaining to flowering and fruiting in three-year-old *H. polyrhizus* plants was collected during the years 2021 and 2022 and the observations were recorded and mentioned under specific headings.

The floral characteristics of *Hylocereus polyrhizus* were observed in the year 2021 and 2022 at various stages i.e., from flower bud initiation to the fruit maturity. The initiation of buds started from the mid-week of May and ended in September in the year 2021 and from first week of May to first week of October in the year 2022. The peak flowering season in the first year (2021) was recorded from June to August with flowering extending until September and for the year 2022, the peak flowering season occurred from May to August and flowering continued until October with 4-5 flushes. The flower opening time at mid-hill conditions of Nagaland varied compared to other regions. The two-year observation of the flowering period indicated that the peak flowering time in the year 2021 was recorded between 10:00 pm to 12:00 pm and from 9:00 pm to 11:00 pm in 2022.

Pushpakumara *et al.* (2005) reported in Sri Lankan conditions that the *Hylocereus* Spp. recorded 4-7 flushes and started flowering from April to

November and sometimes extended to December. Flowering season in Israel started in May and ended in October (Weiss, 1994) whereas in Malaysian conditions Then *et al.* (2020) reported that the peak flowering season in pitaya recorded from March to September. Jiang (2011) stated that the flowering season in yellow pitaya recorded from mid-March to September in Taiwan conditions. In Indian conditions of West Bengal, the flowering period for *Hylocereus costaricensis* recorded between the months of May to November which was similar to the Nagaland conditions. The variation in the results, may be due to the difference in eco physiography (Devi *et al*., 2023).

The flower of the *Hylocereus polyrhizus* remained closed with all the sepaloid tepals covering the petaloid tepals in the evening with the stigma protruding out from the tip of the flower. The flower slowly started opening from 6:00 pm and achieved full bloom between 8:00 pm to 12:00 pm. It varied in different months, in May 2021 and 2022 the flowers usually opened between 10:00 to 12:00 pm which was similar in June 2021 but in June 2022, it was noticed that the flowers started opening early i.e., between 8:00 pm to 12:00 pm. In July 2021, the full bloom was achieved between 9:00 pm to 12:00 pm whereas in 2022 it was between 8:00 pm to 11:00 pm. In August 2021 the flower opened between 9:00 pm to 11:00 pm and in 2022 it was recorded between 8:00 pm to 11:00 pm. The stigma lobes of the flower remained clasped during the opening period and unclasped when flower achieved full bloom and were ready to receive pollen grains. It was observed that the pollen was released even before the flower opened completely. After pollination the flower was open till the next morning and closed by afternoon. The withered flower remained attached to the cladode for few days, eventually dried and fell off leaving the style attached to the ovary.

Hylocereus Spp. in Sri Lanka started blooming around 6.30-7.00 pm and continued till 10.00 pm (Pushpakumara *et al.*, 2005). In Brazilian conditions Muniz *et al.* (2019) stated that the bracts of red dragon fruit flowers slowly started opening around 2:00 pm and flower started initiating anthesis around 6:00 pm and completely opened around 12:00 am. The pollen was released around 5:00 pm before the flower opened completely. In India, Devi *et al.* (2023) reported that flowers of *Hylocereus costaricensis* opened between 5:42 pm to 7:28 pm and closed in the morning around 6:55 to 8:45 am. Patwary (2013) reported that anthesis in flowers of dragon fruit genotypes in Bangladesh conditions started between 3:00 to 4:00 pm and continued till 8:00 to 9:00 pm at night. Time of anthesis in *Hylocereus* spp. in Andaman and Nicobar Islands was recorded between 10:30 to 11:30 pm and duration of anthesis continued to 4-6 hours (Abirami *et al.*, 2021).

Days taken from bud emergence to flowering

The results revealed that the days taken from bud emergence to flower opening varied between 15.32 to 17.40 days in 2021 and 19.90 to 20.35 days in 2022. The variation in the days might be due to the differences in temperatures in the experimental field. In the year 2021 days taken from bud emergence to flower opening was recorded shorter, this might be due to the optimum temperatures prevalent under less rainfall conditions whereas in the year 2022, due to heavy rain falls (in certain months) low temperatures were recorded which might have showed longest duration from bud emergence to flower opening. The mean data recorded stated that the highest number of days taken form bud to flowering (20.35) was recorded in June (2022) and lowest (15.32) in July (2021) (Table 4.11). The results were in close conformity with Muniz (2019) where 14-18 days was observed. In Indian conditions of West Bengal, Devi *et al.* (2023) reported 12-18 days form bud to flower. Silva *et al.* (2015) reported the budding period of 18-23 days at 50% shading. The difference in the budding period to anthesis might be due to the various climatic conditions in different regions or may be due to the shading effect.

The fruiting season of dragon fruit in mid-hill conditions of Nagaland was observed from May to September and sometimes continued till October.

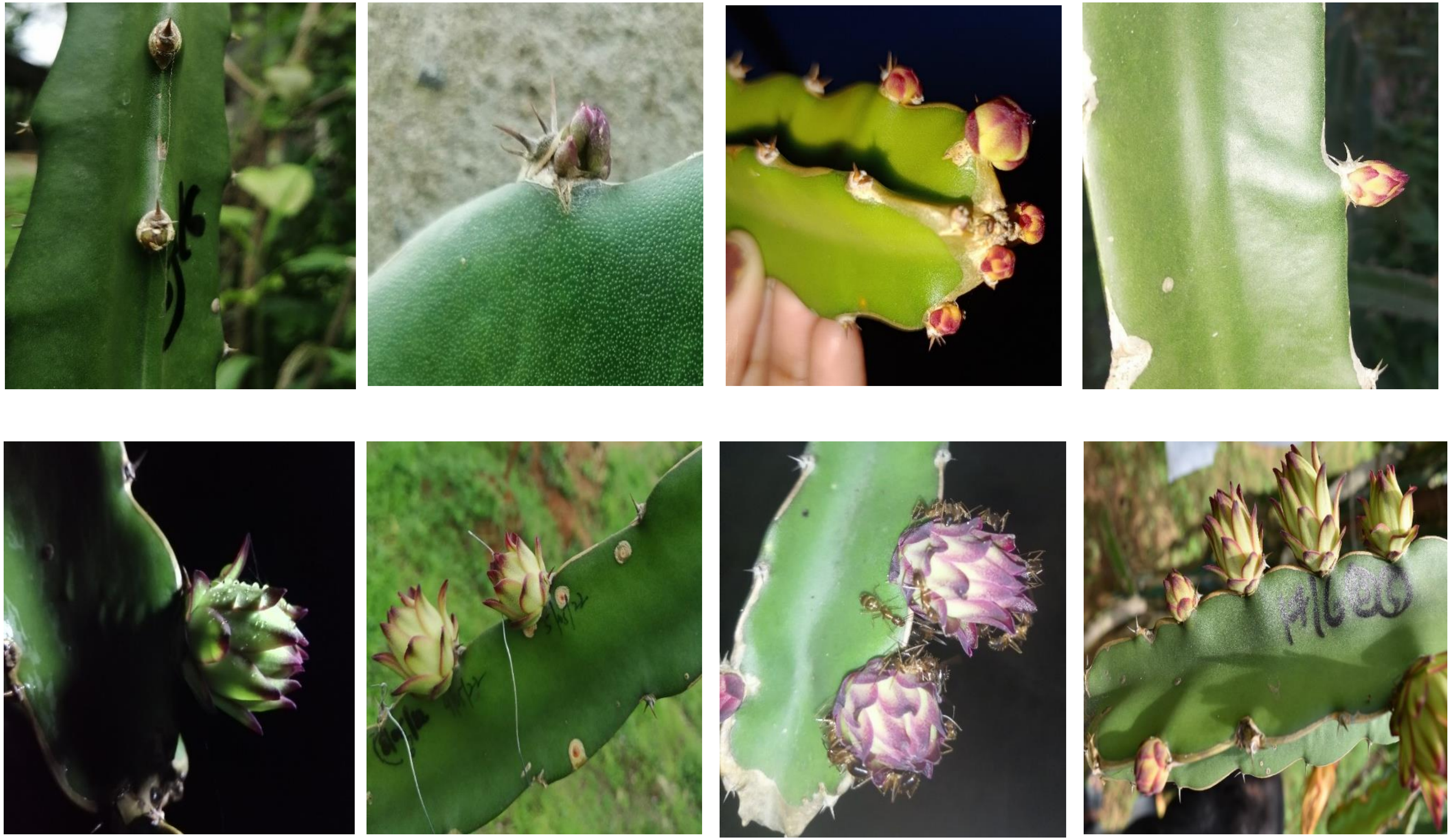


Plate 4.1. Flower bud emergence in dragon fruit

The number of days taken from anthesis to fruit ripening was recorded as 29.00 to 36.00. The fruit of *H. polyrhizus* was medium to large in size, round to oblong in shape with reddish pink flesh and numerous black seeds were scattered inside the pulp. After pollination it took 26-27 days for the fruit to turn from green to pink in colour surrounded with greenish scales. After the fruit turned pink it attained harvesting stage with in four days and harvested by 29-36 days. The weight and size of the fruit varied considerably.

Days taken from anthesis to fruit ripening

During the year 2021-22 the results revealed that the days taken from anthesis to fruit ripening varied between 33.50 to 36.10 in the year 2021 and 29.00 to 35.41 in the year 2022. The mean data recorded stated that the highest number of days taken (36.10) was recorded in August (2021) and the lowest (29.00) in May (2022) (Table 4.11).

Tel-Zur (2011) under Israel conditions reported similar results in pitaya (28 to 41 days) whereas Muniz (2019) in Brazilian conditions reported 30 days from anthesis to fruit ripening and Patwary (2013) under Bangladesh conditions reported that the two genotypes of dragon fruit recorded 32 to 33 days from anthesis to ripening. The variation in number of days for fruiting might be due to the difference in temperature in various locations (Osuna-Enciso *et al.*, 2016). Temperature plays major role and affects the fruit development and maturation in yellow pitaya (Nerd and Mizrahi, 1998).

Floral biology

As per the visual observations, the flower buds of *H. polyrhizus* are greenish red in colour and emerged from the areoles of the mature shoot. Muniz (2019) also reported the bud colour in *H. polyrhizus* as green with red edges. The cylindrical flower buds took an average of 16 to 20 days to open. The flower of dragon fruit observed in the experimental field was creamy white in colour with average length ranging from 25.48 to 30.03 cm, hermaphrodite and nocturnal with sweet fragrance and opened around 8:00 pm

Plate 4.2. Different stages of bud development

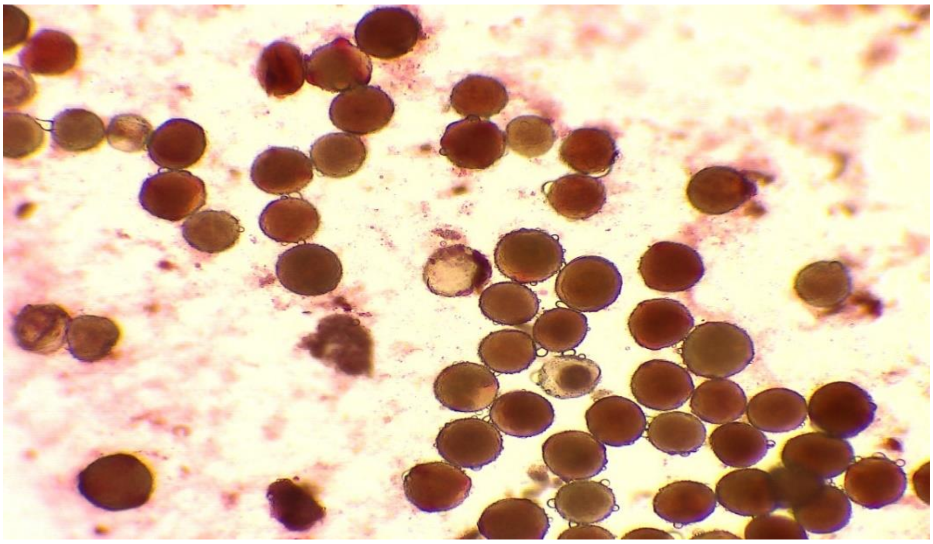
Table 4.11 Flowering and fruiting time in dragon fruit under mid-hill conditions of Nagaland

Month	Days taken from bud emergence to flower opening		Time of flower opening (pm)		Days taken from anthesis to fruit ripening	
	2021	2022	2021	2022	2021	2022
May	15.68	19.60	10:00-12:00	10:00-12:00	No fruits	29.50
June	17.40	20.35	10:00-12:00	8:00-12:00	33.50	32.37
July	15.32	19.75	9:00-12:00	8:00-11:00	34.87	34.06
August	16.86	19.90	9:00-11:00	8:00-11:00	36.10	35.41

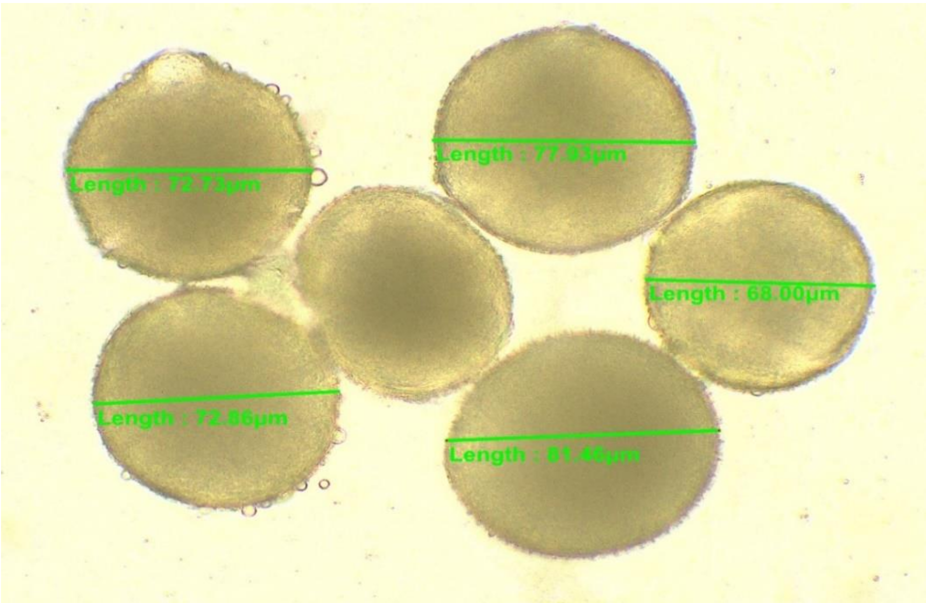
to 12:00 pm. The transverse section of flower indicated that the stamens and style are present at the ventral side of the flower making it Zygomorphic. The perianth is formed from sepaloid tepals and petaloid tepals. The sepaloid tepals are green in colour with different lengths and petaloid tepals are whitish cream in colour, lance-ovate with length ranging from 10.65 to 12.51 cm and 20-23 in number. The stamens are basifixed with yellow anthers with length varying from 7.26 to 11.54 cm and are numerous in number, arranged in a spiral pattern attached to the bottom of the floral tube, distinct and free (apostemonous). The stigma is creamish yellow in colour consisting of many lobes emerging from the rim of the style. The stigma lobe number ranged from 24 to 34 with 1.61 to 2.66 cm length. The tubular hollow style is attached to the ovary at the bottom and stigma at the top. The stamens are positioned below the stigma, the distance between anther to stigma varied much and ranged between 0.63 to 1.63 cm indicating the condition called herkogamy which led to self-incompatibility. The ovary is unilocular and filled with numerous small ovules.

Stigma was one in number with long hollow tubular style with lobes radiating at the tip. The anthesis started around 8:00 pm to 12:00 pm when the lobes of stigma started to unfurl and completely unclasped. Yellowish powder like pollen grain were observed till the next morning.

The pollen of *Hylocereus polyrhizus* was released in massive quantity during the time of anthesis. Pollen from the flower was collected in a vial and was stained with two percent acetocaramine and observed under binocular compound microscope (Magnus MX21i, India) to check the viability. The results revealed that the majority of the pollen grains were stained pink indicating the viability when observed in next morning and the equatorial diameter of pollen grains were noted as 68.00 µm to 81.46 µm. The observations for morphological characteristics of flower for the year 2021 and 2022 has shown below by using tables.



A



B

Plate 4.3. Pollen grains under microscope (A) Pollen grains of *Hylocereus polyrhizus* at 100x magnification (B) Equatorial diameter of pollen grains

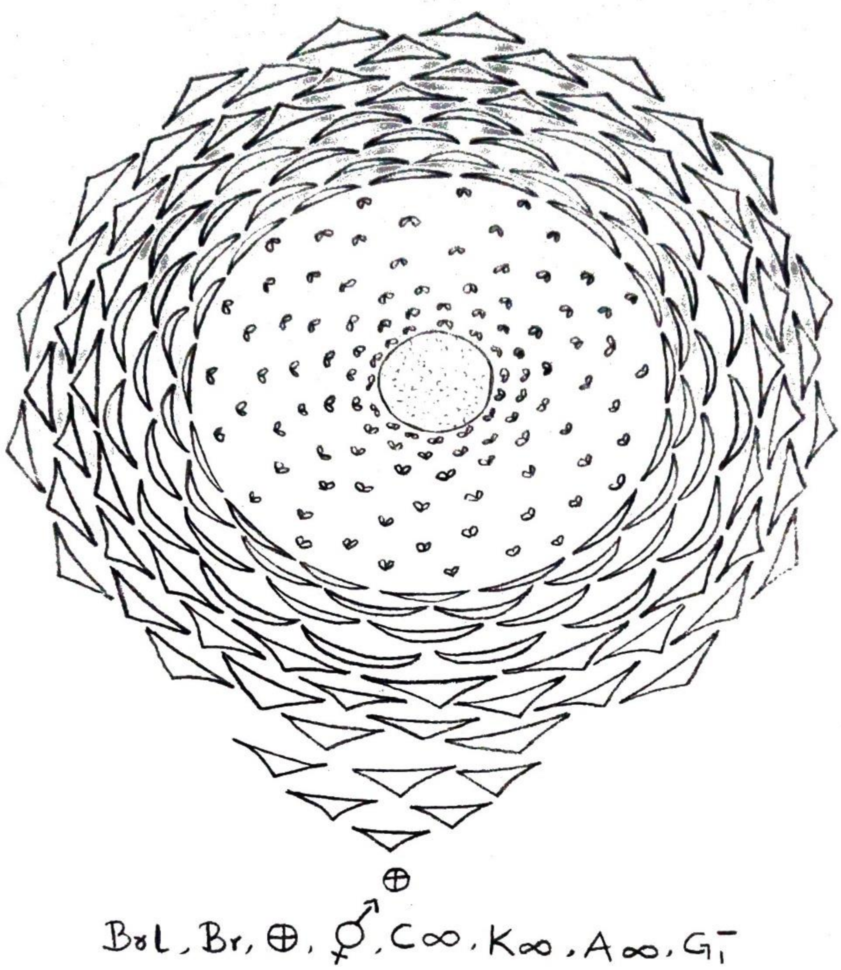


Plate 4.4. Floral formula of *Hylocereus polyrhizus*

4.2.1.1 Pericarp length (cm)

During the year 2021-22 the results revealed that pericarp length varied between 11.25 to 15.30 cm in 2021 and 11.28 to 14.95 cm in 2022 (Table 4.12). The mean data recorded stated that the highest pericarp length (14.82 cm) was recorded in June at 9:00 to 10:00 pm (M_2T_2) and lowest (12.06 cm) in August (M_4T_2). Similar results were obtained in the clone Orejona in Taiwan where the pericarp length varied between 12.10 to 14.5 cm (Tran *et al.,* 2014).

4.2.1.2 Perianth length (cm)

During the year 2021-22 the results revealed that the perianth length varied between 12.35 to 15.83 cm in 2021 and 13.33 to 16.95 cm in 2022. The mean data recorded stated that the highest perianth length (16.25 cm) was recorded in June at 9:00 to 10:00 pm (M_2T_2) and lowest (13.54 cm) in August (M_4T_2) (Table 4.12).

4.2.1.3 Flower length (cm)

The data depicted in table 4.12 indicated that the flower length ranged between 23.93 to 30.23 cm in the year 2021 and 24.79 to 31.74 cm in 2022. The mean data for two years revealed that the highest flower length (30.03 cm) was recorded in the month of June between 10:00 pm to 11:00 pm (M_2T_3) and lowest (25.48 cm) in August between 9:00 to 10:00 pm (M_4T_2). Pushpakumara (2005) reported that the flower length in *Hylocereus* species ranged 20-36 cm in Sri Lanka. Jiang *et al.* (2012) stated that the flowering in pitaya is affected by temperature, light and shoot age.

4.2.1.4 Petal length (cm)

The petal length during the year 2021 was recorded between 10.07 to 12.60 cm and 10.85 to 13.10 in 2022 (Table 4.13). The mean data for both years revealed that the highest (12.60 cm) petal length was recorded in the month of July at (M_3T_4) and lowest (10.65 cm) in June 11.00 to 12.00 pm (M_2T_4).

A

B

C

D

E

F

Plate 4.5. Progression of opening of flower in dragon fruit

Table 4.12 Pericarp, perianth and flower length of dragon fruit

Treatment	Pericarp length (cm)			Perianth length (cm)			Flower length (cm)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-	-	-	-
M_1T_3	11.25	14.29	12.77	12.35	15.75	14.02	23.93	30.10	27.01
M_1T_4	11.92	14.10	13.02	13.07	15.63	14.35	24.93	29.23	27.08
M_2T_1	-	14.33	14.33	-	15.06	15.06	-	29.35	29.35
M_2T_2	-	14.87	14.82	-	16.25	16.25	-	29.81	29.81
M_2T_3	14.27	14.95	14.63	14.13	16.95	15.56	28.32	31.74	30.03
M_2T_4	13.57	13.67	13.65	13.03	14.45	13.78	26.57	27.73	27.15
M_3T_1	-	14.57	14.57	-	15.37	15.37	-	29.42	29.42
M_3T_2	13.57	13.00	13.24	15.83	14.53	15.14	28.97	27.40	28.18
M_3T_3	15.30	12.77	14.02	14.60	13.92	14.25	30.23	26.25	28.24
M_3T_4	14.50	-	14.50	14.70	-	14.70	29.00	-	29.00
M_4T_1	-	13.87	13.87	-	15.61	15.61	-	29.99	29.99
M_4T_2	12.80	11.28	12.06	13.70	13.33	13.54	26.17	24.79	25.48
M_4T_3	14.23	13.38	13.84	13.63	15.19	14.47	28.07	28.07	28.07
M_4T_4	-	-	-	-	-	-	-	-	-
Range (5±)	11.25-15.30	11.28 -14.95	12.06-14.82	12.35 15.83	13.33-16.95	13.54-16.25	23.93 30.23	24.79-31.74	25.48-30.03

Perween and Hasan (2018) reported that the *Hylocereus* species recorded similar petal length under West Bengal conditions.

4.2.1.5 Petal number

Observations recorded for the year 2021 showed that the petal number ranged between 21.00 to 27.33 and 20.13 to 22.60 in 2022. The mean data for two years revealed that the highest petal number (23.73) was recorded in the month of June (M_2T_3) and lowest (20.47) in (M_2T_2) (Table 4.13). Results were in line with Patwary (2013) where the petal number varied between 18-22.

4.2.1.6 Style length (cm)

Style length was ranged between 9.90 to 12.33 cm in the year 2021 and 12.22 to 15.01 cm in 2022. The mean data resulted that highest (14.50 cm) was recorded in June (M_2T_2) and lowest (11.24 cm) in May (M_1T_3) (Table 4.14). The present results were in conformity with the findings of Abirami *et al.* (2021) where style length of four genotypes of *Hylocereus* was studied.

4.2.1.7 Stamen length (cm)

During the year 2021-22 the results revealed that stamen length varied between 6.76 to 7.60 cm in 2021 and 10.39 to 11.50 cm in 2022. The mean data recorded stated that the highest stamen length (11.54 cm) was recorded in June (M_2T_2) and lowest (07.26 cm) in July (M_3T_4) at 11:00 to 12:00 pm (Table 4.14).

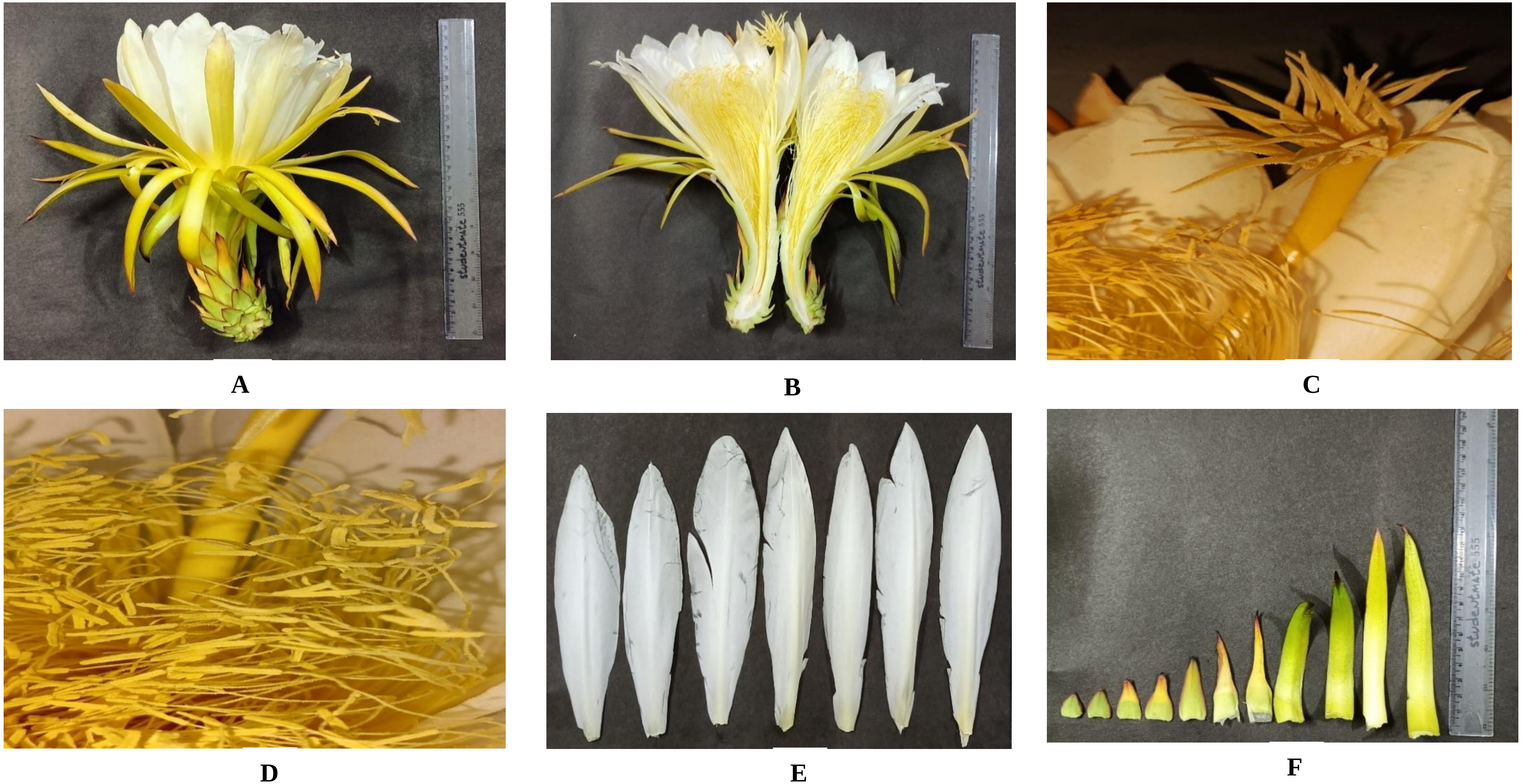


Plate 4.6. Floral parts of *Hylocereus polyrhizus* (A) Flower (B) longitudinal section of flower (C) Stigma, stigma lobes and style (D) Numerous stamens (E) Petals of the flower (F) Sepals of the flower

Plate 4.7. Reproductive phenology of dragon fruit

Table 4.13 Petal length and petal number of flower of dragon fruit

Treatment	Petal length (cm)			Petal number		
	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-
M_1T_3	10.07	11.57	10.82	21.00	20.53	20.75
M_1T_4	11.23	11.94	11.58	21.33	22.20	21.76
M_2T_1	-	12.13	12.13	-	20.67	20.67
M_2T_2	-	12.51	12.51	-	20.47	20.47
M_2T_3	11.03	13.10	12.06	27.33	20.13	23.73
M_2T_4	10.07	11.24	10.65	24.33	21.93	23.13
M_3T_1	-	12.21	12.21	-	21.60	21.60
M_3T_2	12.67	11.34	12.00	22.33	22.93	22.63
M_3T_3	12.50	11.23	11.86	22.67	20.93	21.80
M_3T_4	12.60	-	12.60	23.67	-	23.67
M_4T_1	-	12.25	12.25	-	22.47	22.47
M_4T_2	11.47	10.85	11.15	22.67	22.60	22.63
M_4T_3	11.57	12.07	11.82	24.33	22.00	23.16
M_4T_4	-	-	-	-	-	-
Range (5±)	10.07-12.60	10.85-13.10	10.65-12.60	21.00-27.33	20.13-22.60	20.47-23.73

Table 4.14 Style, stamen length and distance between stigma to anther in flower of dragon fruit

Treatment	Style length (cm)			Stamen length (cm)			Distance between stigma to anther (cm)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-	-	-	-
M_1T_3	9.90	12.58	11.24	7.33	9.25	08.29	1.02	0.72	0.87
M_1T_4	11.27	13.27	12.27	6.76	10.69	08.72	1.20	0.82	1.01
M_2T_1	-	14.39	14.39	-	11.48	11.48	-	1.06	1.06
M_2T_2	-	14.50	14.50	-	11.54	11.54	-	1.42	1.42
M_2T_3	11.23	15.01	13.12	7.43	11.50	09.46	0.88	1.59	1.23
M_2T_4	11.47	13.33	12.30	7.36	10.85	09.10	0.42	0.90	0.66
M_3T_1	-	13.64	13.64	-	11.21	11.21	-	1.25	1.25
M_3T_2	10.33	13.36	11.84	7.60	9.27	08.43	1.31	1.14	1.23
M_3T_3	10.43	13.37	11.90	7.13	10.39	08.76	1.04	1.59	1.32
M_3T_4	12.33	-	12.33	7.26	-	07.26	1.63	-	1.63
M_4T_1	-	13.76	13.76	-	11.24	11.24	-	1.52	1.52
M_4T_2	10.43	12.22	11.32	7.33	9.40	08.36	0.96	1.64	1.30
M_4T_3	10.23	13.86	12.04	6.76	10.85	08.80	0.62	0.65	0.63
M_4T_4	-	-	-	-	-	-	-	-	-
Range (5±)	9.90-12.33	12.22-15.01	11.24-14.50	6.76-7.60	10.39 11.50	7.26-11.54	0.42-1.31	0.65-1.64	0.63-1.63

4.2.1.8 Distance between stigma to anther (cm)

Distance between stigma to anther was ranged between 0.42 to 1.31 cm in the year 2021 and 0.65 to 1.64 cm in 2022 (Table 4.14). The mean data resulted that highest (1.63 cm) was recorded in July M_3T_4 and lowest (0.63 cm) in M_4T_3. Ha *et al.* (2018) and Abhirami *et al*. (2021) recorded the similar results in Taiwan and Andaman and Nicobar in dragon fruit clones (0.10 to 1.70 cm). Weiss *et al*. (1994) reported that the anthers in all *Hylocereus* species were found to be at least 2.00 cm below the stigma. The variations in the plant phenological characteristics from region to region might be the way of plant adaptation to different environmental conditions and may be also due to the different soil and climatic conditions prevalent in those particular regions.

4.2.1.9 Stigma lobe length (cm)

The data pertaining to stigma lobe length in 2021 was ranged between 1.20 to 2.70 cm and 2.18 to 2.51 cm in 2022.The mean data for stigma lobe length was recorded highest (2.66 cm) in July at 11:00 pm to 12:00 pm (M_3T_4) and lowest (1.61 cm) in June (M_2T_4) (Table 4.15). Stigma lobe length recorded highest compared to Perween and Hasan (2018).

4.2.1.10 Number of stigma lobes

The data pertaining to number of stigma lobes during the year 2021 ranged between 21.67 to 34.00 and 24.87 to 30.20. The mean data for two years revealed that the highest stigma lobe number (34.00) was recorded in June (M_3T_4) and lowest (24.37) in June (M_2T_3) (Table 4.15). The results were in slight conformity with Tran *et al.* (2014) where clone VN white recorded highest stigma lobe number (28.00).

4.2.1.11 Fruit size (cm)

The data pertaining to fruit length and breadth during the year 2021 ranged between 6.03 to 8.60 cm to 6.60 to 9.13 cm and 6.43 to 10.13 cm to 6.44

Table 4.15 Stigma lobe length and number of stigma lobes of flower of dragon fruit

Treatment	Stigma lobe length (cm)			Number of stigma lobes		
	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-
M_1T_3	2.33	2.19	2.26	24.67	24.87	24.77
M_1T_4	2.70	2.44	2.57	22.67	28.80	25.73
M_2T_1	-	2.33	2.33	-	26.53	26.53
M_2T_2	-	2.36	2.36	-	27.87	27.87
M_2T_3	1.66	2.88	2.27	21.67	27.07	24.37
M_2T_4	1.20	2.02	1.61	24.00	27.53	25.76
M_3T_1	-	2.50	2.50	-	29.93	29.93
M_3T_2	2.40	2.51	2.45	27.33	30.07	28.70
M_3T_3	2.56	2.32	2.44	24.00	30.20	27.10
M_3T_4	2.66	-	2.66	34.00	-	34.00
M_4T_1	-	2.37	2.37	-	27.80	27.80
M_4T_2	2.60	2.26	2.43	33.00	28.13	30.56
M_4T_3	2.36	2.34	2.35	33.00	28.07	30.53
M_4T_4	-	-	-	-	-	-
Range (5±)	1.20-2.70	2.18-2.51	1.61-2.66	21.67-34.00	24.87-30.20	24.37-34.00

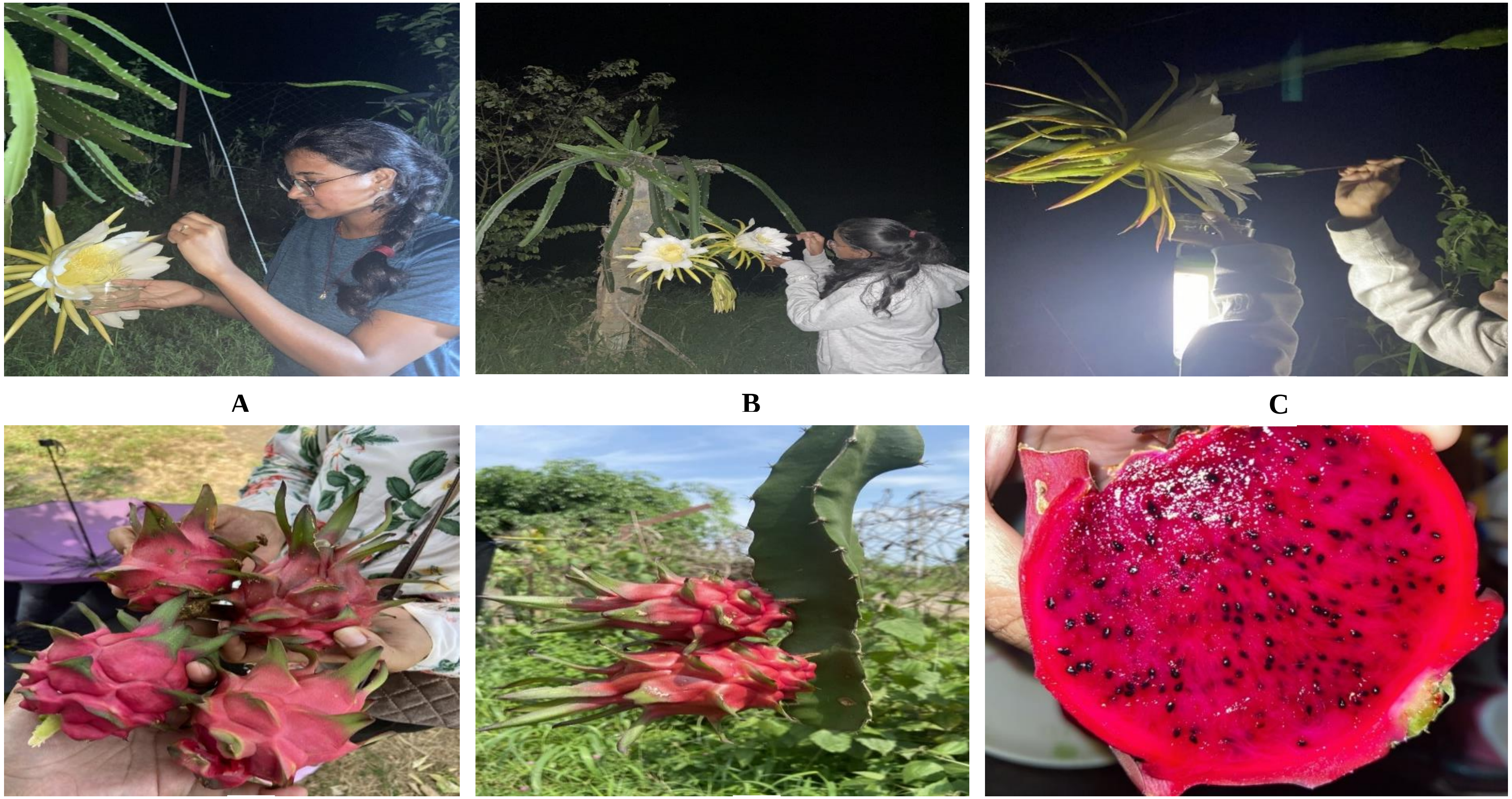
to 8.49 cm in 2022.The mean data for two years revealed that the maximum fruit length (9.19 cm) was recorded in July (M_3T_2) and minimum (6.23 cm) in June (M_2T_1) and breadth was recorded maximum (8.59 cm) in July (M_3T_2) and minimum (6.75 cm) in June (M_2T_1) (Table 4.16). The results of the present study on fruit size are consistent with the previous studies (Parmar, 2020; Abhirami *et al*., 2021, and Singh *et al*., 2022). The increase in the size of the fruit might be due to the rapid cell differentiation, development and maturation in the growing stages (Patel *et al*., 2014).

4.2.1.13 Fruit weight (g)

The data regarding fruit weight for the year 2021 ranged between 184.00 to 398.00 g and 183.00 to 484.00 g in 2022 (Table 4.16). The mean data for two years revealed that the highest fruit weight (441.00 g) was recorded in July (M_3T_2) and lowest (184.00 g) in June (M_2T_1). Tel-Zur *et al.* (2004) reported similar results which are in line with the present findings. Dragon fruit clones grown under Taiwan, Bangladesh and Andaman and Nicobar recorded the similar results (Tran *et al*., 2014; Patwary *et al*., 2013, and Abhirami *et al*., 2021). The increase in the weight might be due to the process of fruit development and maturation where accumulation of sugars, water and other solutes results in increase in the weight at specific growth stage (Chitarra and Chittarra, 2005).

4.2.1.16 Peel weight (g)

The data pertaining to peel weight during the year 2021 ranged between 57.60 to 87.60 g and 59.30 to 130.00 g in 2022 (Table 4.17). The mean data for two years revealed that the highest peel weight (97.60 g) was recorded in June (M_2T_2) and lowest (60.30 g) in June (M_2T_1). Arivalagan *et al*. (2021) reported peel weight between 60 to 174 g in different *Hylocereus* species.



A B C

D E F

Plate 4.8. Pollination of dragon fruit flower (A, B and C) Hand pollination during flower opening (D, E and F) Ripened fruits

Table 4.16 Fruit characteristics of dragon fruit

Treatment	Fruit length (cm)			Fruit width (cm)			Fruit weight (g)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-	-	-	-
M_1T_3	-	7.94	7.94	-	7.08	7.08	-	322.0	322.0
M_1T_4	-	7.79	7.79	-	7.87	7.87	-	288.0	288.00
M_2T_1	6.03	6.43	6.23	6.60	6.91	6.75	185.0	183.0	184.00
M_2T_2	7.83	7.13	7.48	7.59	8.49	8.04	184.0	305.0	245.00
M_2T_3	8.05	7.90	8.68	7.41	7.70	7.55	339.0	327.0	333.00
M_2T_4	-	7.95	7.95	-	7.36	7.36	-	265.0	265.00
M_3T_1	7.39	7.02	7.20	7.14	6.99	7.07	270.0	215.0	242.00
M_3T_2	8.25	10.13	9.19	9.13	8.05	8.59	398.0	484.0	441.00
M_3T_3	8.35	8.44	8.39	7.44	7.59	7.51	298.0	313.0	305.00
M_3T_4	8.06	-	8.06	7.88	-	7.88	303.0	-	303.00
M_4T_1	8.01	8.99	8.50	7.16	8.15	7.65	250.0	285.0	267.00
M_4T_2	-	7.98	7.98	-	7.93	7.93	-	324.0	324.00
M_4T_3	8.60	7.05	7.82	7.93	6.44	7.18	223.0	186.0	204.00
M_4T_4	-	-	-	-	-	-	-	-	-
Range (5±)	6.03-8.60	6.43-10.13	6.23-09.19	6.60-9.13	6.44-8.49	6.75-8.59	184.0-398.0	183.0-484.0	184.0-441.0

Table 4.17 Peel weight and thickness of dragon fruit

Treatment	Peel weight (g)			Peel thickness (mm)		
	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-
M_1T_3	-	80.60	80.60	-	1.71	1.71
M_1T_4	-	69.30	69.30	-	3.67	3.67
M_2T_1	60.30	60.30	60.30	2.23	4.16	3.19
M_2T_2	65.00	130.00	97.60	3.24	6.85	5.04
M_2T_3	77.00	96.60	86.80	2.59	4.35	3.47
M_2T_4	-	59.30	59.30	-	1.97	1.97
M_3T_1	57.60	67.60	62.60	5.36	2.37	3.86
M_3T_2	87.60	89.60	88.60	3.39	2.80	3.10
M_3T_3	85.00	79.00	82.00	3.75	3.62	3.68
M_3T_4	75.60	-	75.60	2.29	-	2.29
M_4T_1	81.60	100.00	90.80	3.09	3.64	3.36
M_4T_2	-	88.30	88.30	-	3.36	3.36
M_4T_3	60.00	61.00	60.50	2.56	3.67	3.11
M_4T_4	-	-	-	-	-	-
Range (5±)	57.6-87.6	59.3-130	60.3-97.6	2.23-5.36	1.71-6.85	1.71-5.04

4.2.1.15 Peel thickness (mm)

During the year 2021-22 the results revealed that the peel thickness varied between 5.36 to 2.23 mm and 6.85 to 1.71 mm (Table 4.17). The mean data recorded stated that the highest peel thickness (5.04 mm) was recorded in June (M_2T_2) and lowest (1.71 mm) in May (M_1T_3). Pushpakumara (2005) reported similar results in Sri Lanka.

4.2.1.14 Pulp weight (g)

The data related to pulp weight was recorded and presented in the table 4.18. The pulp weight ranged between 119.00 to 296.00 g in the year 2021 and 117.00 to 378.00 g in 2022. The mean data for two years revealed that the highest pulp weight (337.00 g) was recorded in the month of July (M_3T_2) and lowest (118.00 g) in June. The results were in conformity with Arivalagan (2021) and Abhirami *et al*. (2021).

4.2.1.17 Pulp (%)

The data pertaining to pulp percentage during the year 2021 ranged between 64.32 to 80.71% and 63.93 to 78.09% in 2022 (Table 4.18). The mean data for two years revealed that the highest pulp percentage (78.14%) was recorded in June (M_2T_2) and lowest (63.12%) in June (M_2T_1).

4.2.1.18 TSS (°Brix)

The data depicted in table 4.19 indicated that the TSS ranged between 10.3 to 16.1 °Brix in the year 2021 and 9.76 to 16.30°Brix in 2022. The mean data for two years revealed that the highest TSS was recorded as 16.30 °Brix in the month of June (M_2T_4) and lowest (12.50 °Brix) in July (M_3T_4) (Table 4.19).

The present findings were in conformity with Ha *et al.*, (2018); Abhirami *et al*., (2021) and Pushpakumara (2005). The increase in TSS might be due to

Table 4.18 Pulp weight and pulp percentage of dragon fruit

Treatment	Pulp weight (g)			Pulp (%)		
	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-
M_1T_3	-	237.00	237.00	-	73.60	73.60
M_1T_4	-	215.00	215.00	-	74.65	74.65
M_2T_1	119.00	117.00	118.00	64.32	63.93	63.12
M_2T_2	147.00	233.00	190.00	79.89	76.39	78.14
M_2T_3	253.00	245.00	249.00	74.63	74.92	74.77
M_2T_4	-	171.00	171.00	-	64.52	64.52
M_3T_1	199.00	143.00	171.00	73.70	67.13	70.41
M_3T_2	296.00	378.00	337.00	74.37	78.09	76.41
M_3T_3	222.00	215.00	219.00	74.49	68.69	71.59
M_3T_4	223.00	-	223.00	73.59	-	73.59
M_4T_1	178.00	187.00	182.00	71.20	65.61	68.40
M_4T_2	-	208.00	208.00	-	64.19	64.19
M_4T_3	180.00	140.00	160.00	80.71	75.26	77.98
M_4T_4	-	-	-	-	-	-
Range (5±)	119.00-296.00	117.00-378.00	118.00-337.00	64.32-80.71	63.93-78.09	63.12-78.14

the degradation of starch and its metabolic transformation in to sugars (Chitarra and Chittarra, 2005).

4.2.1.19 Titratable acidity (%)

During the year 2021-2022 the results revealed that the acidity varied between 0.11 to 0.23% and 0.10 to 0.25%. The mean data recorded stated that the highest acidity (0.21%) was recorded in the month of July (M_3T_4) and lowest (0.10%) in August (M_4T_2) (Table 4.19). Similar results were recorded by Abirami *et al.,* (2021) where acidity ranged between 0.2 to 0.3%.

The titratable acid content in *Hylocereus* has recorded low compared to other studies the decrease in the acid content might be due to the utilisation of organic acids in the respiration process as substrate or may be due to the conversion of starch in to sugars during maturation (Chitarra and Chittarra, 2005).

4.2.1.20 TSS: acid

The data related to TSS/acid was recorded and presented in the table 4.19. It ranged between 28.33 to 92.48 in the year 2021 and 71.93 to 142.10 in 2022. The mean data for two years revealed that the highest TSS/ acid (142.10) was recorded in the month of August (M_4T_2) and lowest (59.52) in July. Similar results were obtained by Centurión Yah *et al*. (2008) and Sethunath (2019) in Kerala where the ratio was between 91.67 to 150.00. The low titratable acid values attributed to high very high TSS: acid ratio.

4.2.1.21 Reducing sugars (%)

The data regarding to reducing sugars for the year 2021 ranged between 4.78 to 6.63 % and 3.89 to 7.89 % in 2022 (Table 4.20) The mean data for two years revealed that the maximum reducing sugar (6.98 %) was recorded in the month of June (M_2T_4) and minimum (3.89 %) in May (M_1T_3). The results were

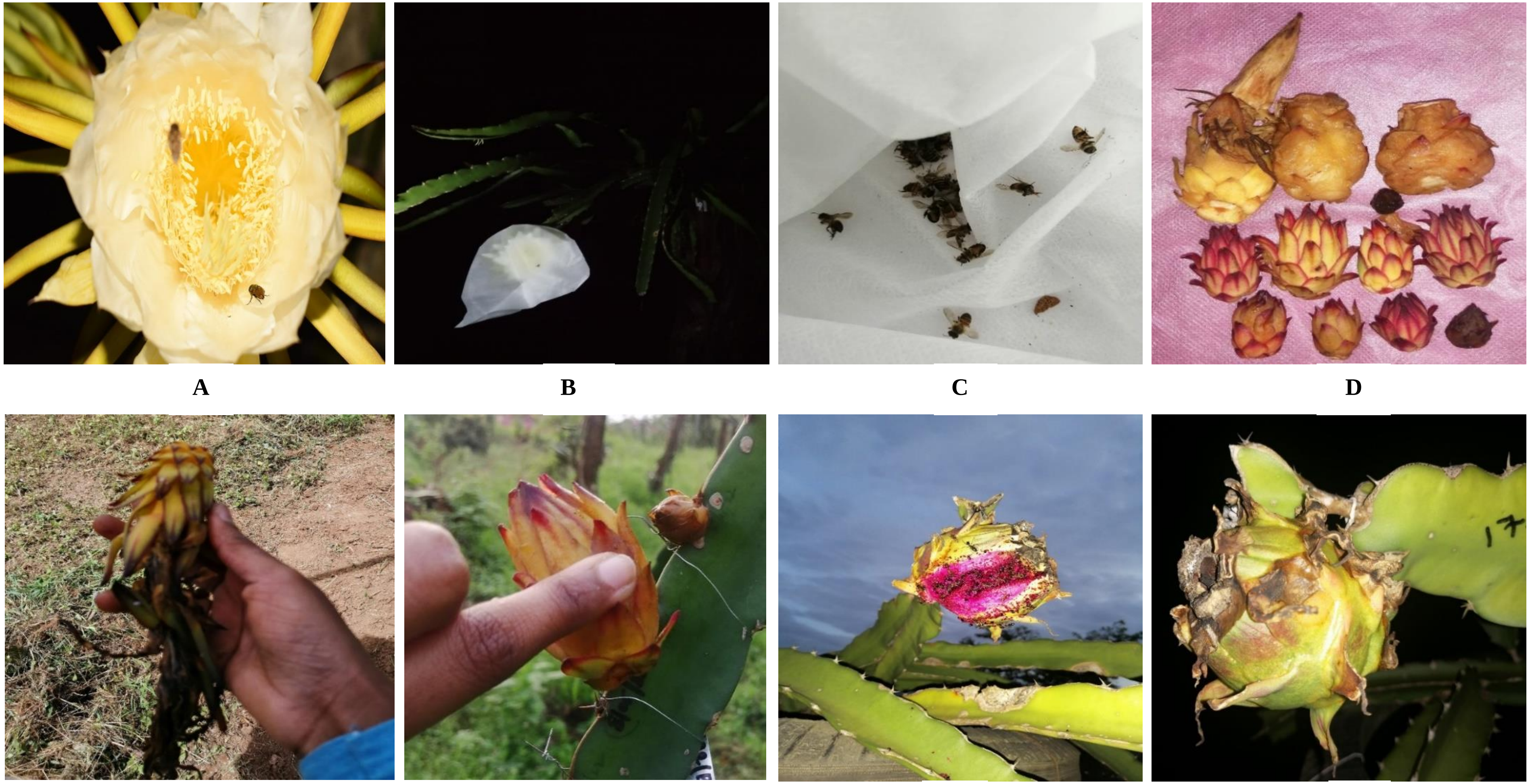


Plate 4.9. Pollinators, bud drop, fruit splitting and sunburn (A, B and C) Pollinators visiting flower (D, E and F) Bud drop due to excess rainfall G) Fruit splitting H) Sunburn of fruit

Table 4.19 Quality characteristics of dragon fruit

Treatment	TSS (ºB)			Titratable acidity (%)			TSS/acid		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-	-	-	-
M_1T_3	-	12.80	12.80	-	0.14	0.14	-	88.68	88.68
M_1T_4	-	15.10	15.10	-	0.19	0.19	-	89.86	89.86
M_2T_1	16.00	16.00	16.00	0.13	0.13	0.13	75.62	121.80	98.75
M_2T_2	14.50	12.80	13.60	0.13	0.25	0.19	75.91	55.16	65.53
M_2T_3	15.50	15.40	15.40	0.11	0.19	0.15	92.48	97.20	94.84
M_2T_4	-	16.30	16.30	-	0.12	0.12	-	135.83	135.83
M_3T_1	12.20	15.20	13.70	0.23	0.11	0.17	28.33	137.90	83.15
M_3T_2	11.40	15.40	13.40	0.12	0.09	0.10	49.92	172.10	111.00
M_3T_3	15.90	15.50	15.70	0.13	0.11	0.12	82.78	138.00	110.40
M_3T_4	12.50	-	12.50	0.21	-	0.21	59.52	-	59.52
M_4T_1	16.10	9.76	12.90	0.20	0.13	0.16	55.03	71.93	63.48
M_4T_2	-	13.50	13.50	-	0.10	0.10	-	142.10	142.10
M_4T_3	10.30	14.80	12.60	0.14	0.12	0.13	47.62	124.10	85.91
M_4T_4	-	-	-	-	-	-	-	-	-
Range (5±)	10.3-16.1	9.76-16.3	12.5-16.0	0.11-0.23	0.10-0.25	0.10-0.21	28.33-92.48	71.93-142.1	59.52-142.1

in close conformity with Arivalagan *et al*. (2021) Trong *et al.* (2022) reported that the rise in sugars during the fruit maturation process in dragon fruit.

4.2.1.22 Total sugars (%)

During the year 2021-22 the results revealed that total sugars varied between 6.32 to 7.97 % and 5.79 to 9.49 % (Table 4.20). The mean data recorded stated that the maximum total sugars (9.21 %) was recorded in May (M_1T_4) and minimum (6.05 %) in July (M_3T_4). Similar results were reported by Islam *et al*. (2012) in Bangladesh and Parmar (2020) in Gujarat where total sugar content was recorded as 8.00 % and 9.19 %. Sucrose accumulation during the fruit maturity period might have resulted in increase in total sugar content in red dragon fruit or might be due to the hydrolysis of starch in to sugars (Chandra, 1990 and Burger and Schaffer, 2007).

4.2.1.23 Non-reducing sugars (%)

The data depicted in table 4.20 indicated that the non-reducing sugars ranged between 0.53 to 3.19 % in the year 2021 and 0.19 to 4.30 % in 2022. The mean data for two years revealed that the highest non-reducing sugars was recorded as 4.30 % in the month of May (M_1T_3) and lowest (0.19 %) in August (M_4T_2). The results were in close conformity with Islam *et al.* (2012).

4.2.1.24 Ascorbic acid (mg/100 g)

The data pertaining to ascorbic acid content during the year 2021 ranged between 2.80 to 3.54 mg/100 g and 2.61 to 4.10 mg/100 g in 2022 (Table 4.21). The mean data for two years revealed that the highest ascorbic acid content (3.45 mg/100 g) was recorded in June (M_2T_4) and lowest (2.52 mg/100 g) in August (M_4T_3). The ascorbic acid content in red dragon fruit in mid hill conditions of Nagaland recorded very less compared to other regions. The agro climatic conditions, orchard management, growing conditions, maturity period might have influenced the vitamin-C content (Lee and Kader, 2000).

Table 4.20 Sugar content of dragon fruit under mid-hill condition of Nagaland

Treatment	Reducing sugars (%)			Total sugars (%)			Non-reducing sugars (%)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-	-	-	-
M_1T_3	-	3.89	3.89	-	8.20	8.20	-	4.30	4.30
M_1T_4	-	6.51	6.51	-	9.21	9.21	-	2.70	2.70
M_2T_1	5.79	5.62	5.71	6.96	7.11	7.04	1.17	1.49	1.33
M_2T_2	5.27	7.75	6.51	7.10	6.70	6.90	0.38	0.40	0.39
M_2T_3	4.12	5.44	4.78	8.86	7.08	7.97	3.45	2.93	3.19
M_2T_4	-	6.98	6.98	-	8.40	8.40	-	1.42	1.42
M_3T_1	6.00	5.27	5.63	7.73	6.49	7.11	1.73	1.22	1.48
M_3T_2	5.32	5.66	5.49	7.91	7.89	7.90	2.59	2.23	2.41
M_3T_3	5.58	5.83	5.71	7.42	7.42	7.42	1.84	1.59	1.71
M_3T_4	5.25	-	5.25	6.05	-	6.05	0.80	-	0.80
M_4T_1	6.22	6.27	6.24	6.75	8.03	7.39	0.53	1.76	1.15
M_4T_2	-	6.67	6.67	-	6.86	6.86	-	0.19	0.19
M_4T_3	6.63	7.13	6.88	7.91	7.36	7.64	1.28	0.23	0.76
M_4T_4	-	-	-	-	-	-	-	-	-
Range (5±)	4.78-6.63	3.89-7.89	3.89-6.98	6.32-7.97	5.79-9.49	6.05-9.21	0.53-3.19	0.19-4.30	0.19-4.30

Table 4.21 Bio-chemical characteristics of dragon fruit

Treatment	Ascorbic acid (mg/100 g)			Peel phenolic content (mg GAE/100g)			Pulp phenolic content (mg GAE/100g)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-	-	-	-
M_1T_3	-	2.80	2.80	-	40.4	40.4	-	44.8	44.8
M_1T_4	-	3.36	3.36	-	47.7	47.7	-	51.9	51.9
M_2T_1	2.98	3.17	3.08	49.7	50.6	50.1	43.2	44.6	43.9
M_2T_2	2.80	2.61	2.70	51.5	40.1	45.8	52.3	37.7	45.0
M_2T_3	2.97	3.54	3.26	46.0	47.1	46.6	47.7	43.4	45.6
M_2T_4	-	3.45	3.45	-	39.5	39.5	-	45.6	45.6
M_3T_1	2.89	2.80	2.84	54.9	47.1	51.0	40.3	43.4	41.8
M_3T_2	3.54	2.98	3.26	54.4	43.1	48.8	56.6	39.3	47.9
M_3T_3	2.92	3.30	3.11	45.8	47.4	46.6	46.5	47.7	47.1
M_3T_4	2.80	-	2.80	38.1	-	38.1	43.2	-	43.2
M_4T_1	2.93	2.29	2.61	40.6	65.0	52.8	39.4	54.8	47.1
M_4T_2	-	2.80	2.80	-	49.4	49.4	-	45.4	45.4
M_4T_3	2.42	2.61	2.52	61.5	57.6	59.5	48.9	38.0	52.0
M_4T_4	-	-	-	-	-	-	-	-	-
Range (5±)	2.80-3.54	2.61-4.10	2.52-3.45	38.1-61.5	39.5-65.0	38.1-59.5	39.4-56.6	37.7-54.8	41.8-52.0

4.2.1.25 Peel phenolic content (mg GAE/100g)

The data regarding peel phenolic content for the year 2021 ranged between 38.10 to 61.50 mg GAE/100 g and 39.50 to 65.00 mg GAE/100 g in 2022 (Table 4.21). The mean data for two years revealed that the maximum peel phenolic content (59.50 mg GAE/100 g) was recorded in the month of August (M_4T_3) and minimum (38.10 mg GAE/100 g) in July (M_3T_4) (Table 4.13). Similar results were reported by and Arivalagan *et al.* (2021) and Abhirami *et al*. (2021) where phenolic content in peel recorded higher than pulp in *Hylocereus* spp. Caro and Piga (2007) reported similar results in peel of fresh Italian figs. Nurliyana (2010) stated that the peels contained less phenolic content than pulp of red dragon fruit compared to white dragon fruit cultivars. This might be due to the presence of different antioxidant compounds in peel or not all vegetable, fruit and their derivatives have the same phenolic composition (Verzelloni *et al*., 2007).

4.2.1.26 Pulp phenolic content (mg GAE/100g)

The data regarding pulp phenolic content for the year 2021 ranged between 39.40 to 56.60 mg GAE/100g and 37.70 to 54.80 mg GAE/100g in 2022 (Table 4.21). The mean data for two years revealed that the maximum phenolic content in pulp (52.00 mg GAE/100 g) was recorded in the month of August (M_4T_3) and minimum (41.80 mg GAE/100 g) in July (M_3T_1). Results were in conformity with Nurliyana (2010) where pulp of red flesh dragon fruit has recorded high phenolic content compared to white flesh. The high phenolic content in the pulp might be due to the red colour in the flesh of *Hylocereus polyrhizus* and might also be due to the presence of betalain compounds. Jiang (2021) reported that pitaya have high phenolic content than other tropical fruits.

4.2.1.27 Peel betacyanin content (mg/100g)

The data pertaining to peel betacyanin content during the year 2021 ranged between 21.24 to 39.89 mg/100 g and 21.54 to 47.35 mg/100 g in 2022

Plate 4.10. Fruits of *Hylocereus polyrhizus*

Table 4.22 Peel and pulp betacyanin content characteristics of dragon fruit

Treatment	Peel betacyanin content (mg/100g)			Pulp betacyanin content (mg/100g)		
	2021	2022	Pooled	2021	2022	Pooled
M_1T_1	-	-	-	-	-	-
M_1T_2	-	-	-	-	-	-
M_1T_3	-	33.17	33.17	-	31.99	31.99
M_1T_4	-	26.62	26.62	-	39.35	39.35
M_2T_1	39.89	34.80	37.34	33.73	36.81	35.27
M_2T_2	35.78	42.14	38.96	33.17	40.07	36.62
M_2T_3	35.28	32.51	33.89	25.61	35.49	30.55
M_2T_4	-	25.41	25.41	-	31.73	31.73
M_3T_1	36.13	47.35	41.74	29.35	29.14	29.24
M_3T_2	35.78	36.17	35.97	29.88	28.22	29.05
M_3T_3	37.22	35.13	36.17	33.34	27.26	30.33
M_3T_4	22.18	-	22.18	21.34	-	21.34
M_4T_1	21.24	40.34	30.79	18.75	26.14	22.44
M_4T_2	-	25.86	25.86	-	24.08	24.08
M_4T_3	22.22	21.54	21.88	25.05	24.45	24.75
M_4T_4	-	-	-	-	-	-
Range (5±)	21.24-39.89	21.54-47.35	21.88-41.74	18.75-33.73	24.08-40.07	21.34-39.35

(Table 4.22). The mean data for two years revealed that the maximum betacyanin content in the peel (41.74 mg/100 g) was recorded in July (M_3T_1) and minimum (21.88 mg/100 g) in August (M_4T_3). Halimfanezi (2020) reported 36.67 mg/100 g of betacyanin content in peel of *Hylocereus polyrhizus.* Stintzing *et al.* (2022) stated that the red colour of peels might be due to the presence of betacyanin pigment in mature fruits.

4.2.1.28 <u>Pulp betacyanin content (mg/100g)</u>

The data depicted in table 4.22 indicated that the betacyanin content in the pulp of dragon fruit ranged between 18.75 to 33.73 mg/100 g in the year 2021 and 24.08 to 40.07mg/100 g in 2022. The mean data for two years revealed that the highest betacyanin content in pulp was recorded as 39.35 mg/100 g in the month of May (M_1T_4) and lowest 21.34 mg/100 g in July (M_3T_4). The present findings recorded high betacyanin content in pulp compared to Arivalagan *et al.* (2021) who reported betacyanin content in pulp of red flesh dragon fruit as 14.4 to 23.0 mg/100 g. The red colour of flesh may be due to the presence of betalains a nitrogen containing pigment. Wu *et al*. (2019) reported the increase in the betacyanin content during the fruit development period.

4.2.2 Correlation analysis

The correlation studies were carried out to know the impact of climatic variables like temperature, relative humidity, rainfall and sunshine hours on flower and fruit characteristics of *Hylocereus polyrhizus* grown in Nagaland. The correlation coefficient was worked out for the above characters and are presented in the tables along with figures.

Data regarding correlation studies revealed that the days taken from bud to flowering was significantly correlated with temperature (0.693*) and was not influenced by relative humidity (0.158) and rainfall (0.425) but had strong negative correlation with sunshine hours (-0.078) (Table 4.24). Jiang *et al*. (2011) and Khaimov *et al*. (2006) reported that the temperature and day length

Table 4.23 Correlation of climatic conditions with flower parameters in red dragon fruit

Parameters	Temperature (°C)	Relative Humidity (%)	Rainfall (mm)	Sunshine (hours)
Days taken from bud to flowering	0.693*	0.158	0.425	-0.078
Flower length (cm)	0.285	0.483	0.508*	-0.060
Petal length (cm)	0.284	0.349	0.535*	0.021
Petal number	0.334	0.159	0.539*	0.180
Style length (cm)	0.309	0.166	0.438	0.104
Stamen length (cm)	0.221	0.270	0.380	0.049
Stigma lobe length (cm)	0.313	0.251	0.293	0.221
Stigma lobe number	0.447	0.238	0.163	0.226
Pericarp length (cm)	0.246	0.369	0.465	-0.091
Perianth length (cm)	0.196	0.359	0.403	-0.006
Distance between stigma to anther (cm)	0.419	0.281	0.162	0.204

alone cannot induce the flower bud formation in pitaya species. Experiments conducted by Nerd *et al*. (2002) in Taiwan reported that the red flesh species of dragon fruit require shorter day length and low temperatures for flower initiation compared to other species. Nobel and De la Barrera (2002) and Smith *et al*. (1984) reported that pitaya has less tolerance to high temperatures compared to other 18 cactus species. Flower length, petal length, petal number had significant correlation with rainfall (0.508*, 0.535*, 0.539*) and had not been influenced by temperature and relative humidity. Flower length had strong negative correlation with sunshine hours (-0.06). Parameters like style length, stamen length, stigma lobe length, number of stigma lobes, pericarp length, perianth length and distance between stigma to anthers were not been influence by climatic factors except for pericarp and perianth length which had strong negative correlation with sunshine hours (-0.091 and -0.006). Nerd and Mizrahi (1995) reported that climatic factors like temperature, rainfall, relative humidity and photoperiod have direct effect on flowering and fruit set in cacti. Days taken from anthesis to fruit ripening showed high positive correlation with temperature (0.758**). Temperature played major role and affected the fruit development and maturation in yellow pitaya (Nerd and Mizrahi, 1998) but extreme temperatures beyond 38 ºC resulted poor fruit set and reduced fruit weight in *Hylocereus polyrhizus* (Chu and Chang, 2020). Sunshine hours (-0.039) showed strong negative correlation whereas other factors like rainfall and relative humidity didn’t influenced days taken from anthesis to fruit ripening. Fruit weight, fruit length and breadth had high positive correlation with rainfall (0.836**, 0.725** and 0.720**). Fruit weight, fruit length, pulp weight and peel weight had significantly correlated with relative humidity (0.598*, 0.593*, 0.584* and 0.510*). Kour *et al.* (2015) reported that fruit weight positively correlated with relative humidity in Grande peach. Pulp weight, peel weight and pulp (%) had significantly correlated with rainfall. Sunshine hours showed strong negative

Table 4.24 Correlation of climatic conditions with fruit parameters in red dragon fruit

Parameters	Temperature (°C)	Relative Humidity (%)	Rainfall (mm)	Sunshine (hours)
Days taken from anthesis to fruit ripening	0.758**	0.269	0.321	-0.039
Fruit weight (g)	0.460	0.598*	0.836**	-0.061
Fruit length (cm)	0.343	0.593*	0.725**	0.043
Fruit breadth (cm)	0.216	0.488	0.720**	-0.047
Pulp weight (g)	0.236	0.584*	0.674*	-0.101
Peel thickness (mm)	0.176	0.419	0.474	-0.138
Peel weight (g)	0.203	0.510*	0.521*	0.016
Pulp (%)	0.197	0.437	0.571*	-0.094

Table 4.25 Correlation of climatic conditions with quality parameters in red dragon fruit

Parameters	Temperature (°C)	Relative Humidity (%)	Rainfall (mm)	Sunshine (hours)
TSS (ºB)	0.653*	0.115	-0.412*	-0.003
Titratable acidity (%)	-0.448*	0.030	0.212	-0.262
TSS/acid	0.571*	0.044	-0.304	0.163
Reducing sugars (%)	0.193	0.113	-0.481*	-0.025
Total sugars (%)	0.537*	0.180	-0.369	-0.134
Non-reducing sugars (%)	0.417	0.232	0.092	-0.186
Ascorbic acid (mg/100g)	-0.003	0.082	0.210	-0.133
Peel phenolic content (mg GAE/100g)	-0.214	0.118	0.13	-0.091
Pulp phenolic content (mg GAE/100g)	-0.184	0.05	0.001	-0.092
Peel betacyanin content (mg/100g)	0.713**	0.312	-0.076	-0.054
Pulp betacyanin content (mg/100g)	0.549*	0.217	-0.012	-0.270

influence on fruit weight (-0.061), fruit breadth (-0.047) and pulp percentage (-0.094) (Table 4.24).

According to table 4.25 the results indicated that the TSS was significantly correlated with temperature (0.653*) and had negative correlation with rainfall (-0.412*). Similar results were observed by Dolkar *et al*. (2018) in Kinnow mandarin. TSS showed strong negative correlation with sunshine hours (-0.003). Titratable acidity showed negative correlation with temperature (-0.448*). Dolkar *et al*. (2018) reported that acidity showed negative correlation with temperature in Kinnow mandarin. Kliewer and Lider (1970) reported that during the fruit growth period the malic acid synthesis was more sensitive to high temperatures. Relative humidity, rainfall and sunshine hours didn't influence acidity. TSS/acid and total sugars had significantly correlated with temperature (0.571* and 0.537*). The results are in close conformity with Dolkar *et al.* (2018) who reported that maximum and minimum temperatures positively favoured the sugar acid ratio in Kinnow mandarin. Other factors like relative humidity, rainfall and sunshine hours had no influence on the above parameters. Reducing sugars showed negative correlation with rainfall (-0.481*). Peel betacyanin content showed high positive correlation with temperature (0.713**) and pulp betacyanin content showed significant correlation with temperature (0.549*). The results were in close conformity with Chang *et al.* (2016) who reported that the red pitaya grown under 50 to 75% (reduced temperature to 6 to 7ºC) shade accumulated more betacyanin content in the peel. High temperature with high light intensity resulted in delay of betacyanin pigment accumulation in peels of *Hylocereus* Species. Chu (2020) also reported the reduction of colour in red dragon fruit when exposed to high temperature treatments which suppressed the betacyanin pigments on the fruits exposed to sunlight. Rainfall showed strong negative correlation for both parameters (-0.076 and -0.012). Parameters like reducing sugars, peel and pulp phenolic content and pulp betacyanin content showed strong negative correlation with sunshine hours.

4.3 Betacyanin pigment stability in peel and pulp

The data pertaining to the effect of pH and solvents on betacyanin content of *Hylocereus polyrhizus* peel and pulp are presented below:

4.3.1 Effect of pH and solvents on peel extracts on different days of storage

4.3.1.1 Day-1

The data on stability of betacyanin pigment in the peel of dragon fruit as influenced by different solvents and levels of pH was recorded and presented in table 4.26a and 4.26b.

Individual effect of different solvents at different pH levels showed non-significant effect on the stability of betacyanin pigment in peel. The pooled data showed that there was a significant variation. The highest extraction (34.71 mg/100g) was recorded in S_3 (distilled water) and lowest (23.46 mg/100g) in S_1 (acetone). Data on the different pH levels showed that the highest betacyanin content was recorded at pH_6 (30.38 mg/100g) and lowest at pH_1 (28.96 mg/100g).

The pooled data pertaining to the interaction effect of different solvents at different pH levels are presented in Fig 4.9 and results indicated that there was a significant variation noticed among the treatments during the year 2021 and treatments were found non-significant during the year 2022. The highest (36.05 mg/100g) betacyanin content in peel was recorded in the treatment S_3P_1 (distilled water at pH 1) and the lowest (20.27 mg/100g) values were recorded under S_1P_6 (acetone at pH 6).

4.3.1.2 Day-2

Adoption of different solvents to extract betacyanin pigment in peel of red dragon fruit at different pH levels showed significant variation during both the years (Table 4.26a). Methanol (S_2) recorded highest betacyanin content (46.51 mg/100g) in the year 2021 and 30.48 mg/100g in distilled water (S_3) in

2022. But methanol (S_2) showed highest in pooled (33.42 mg/100g), acetone (S_1) recorded constantly lower betacyanin content in both the years as well as in pooled with a 13.74, 13.88 and 13.81 mg/100g respectively.

Different pH levels influenced betacyanin content significantly. The highest pigment concentration in peel (34.36, 23.24 and 28.80 mg/100g) was recorded at pH_3 in both the years as well as in pooled data and lowest (24.48, 18.67 and 21.57 mg/100g) at pH_6.

The data on interaction effect of solvents at different pH levels revealed significant variation on Day -2. Pooled analysis of data revealed that the highest betacyanin pigment concentration in peel (37.17 mg/100g) was recorded in the treatment S_2P_6 (methanol at pH 6) followed by treatment S_2P_3 (35.42 mg/100g) and lowest (10.42mg/100g) in S_1P_6 (Fig 4.9).

4.3.1.3 Day-3

Data in table 4.26a showed that betacyanin pigment in peel of *H. polyrhizus* was influenced by different pH levels and solvents. Individual effect of different solvents on pigment extraction showed significant variation. The highest betacyanin content in peel (34.80 mg/100g) was recorded in S_2 (methanol) and lowest (12.90 mg/100g) in S_1 (acetone).

Data on betacyanin pigment concentration in peel was influenced by different levels of pH. The maximum (26.60 mg/100g) was recorded in P_3 (pH 3) and the minimum (18.80 mg/100g) recorded in P_6 (pH 6) (Table 4.26a).

The data pertaining to the interaction effect on different solvents and levels of pH on betacyanin content in peel of red dragon fruit are presented in Fig 4.9. The results indicated that the maximum pigment content (37.12 mg/100g) was recorded under the treatment S_2P_3 (methanol at pH 3) and minimum (10.76 mg/100g) under S_1P_6 (acetone at pH 6).

4.3.1.4 Day-4

Data in table 4.26a showed that the betacyanin pigment content in peel was influenced by different pH levels and solvents. The pooled data showed that the different solvents had significant effect on the betacyanin content in peel. The highest pigment content (24.35 mg/100g) was recorded in S_3 (distilled water) and lowest (10.38 mg/100g) in S_1 (acetone).

Similarly, data on betacyanin pigment concentration in peel was influenced by different levels of pH. The maximum (20.43 mg/100g) was recorded in P_3 (pH 3) and the minimum (13.70 mg/100g) recorded in P_6 (pH 6).

The data pertaining to the interaction effect on different solvents and levels of pH on betacyanin content in peel of dragon fruit are presented in Fig 4.9. The results indicated that maximum pigment content (32.76 mg/100g) was recorded under the treatment S_3P_3 (distilled water at pH 3) and minimum (7.95 mg/100g) under S_1P_3 (acetone at pH 3).

4.3.1.5 Day-5

Experimental results in table 4.26a indicated that there is a significant variation for betacyanin content in peel of dragon fruit when extracted with different solvents at different pH levels. Among different treatments, on Day-5, distilled water (S_3) gave maximum extraction of betacyanin pigment in peel (22.39 mg/100g) and minimum (8.07 mg/100g) by acetone (S_1).

Data on different levels of pH showed significant difference for betacyanin content in peel of *Hylocereus polyrhizus*. The maximum pigment content (18.03 mg/100g) was recorded at pH_3 and minimum (10.75 mg/100g) at pH_6.

Interaction effect between solvents and pH levels combination significantly varied at storage. On Day-5 the highest betacyanin content in peel (31.52 mg/100g) was recorded in the treatment S_3P_3 (distilled water at pH 3). Whereas S_2P_1 (methanol at pH 1) recorded lowest betacyanin (5.14 mg/100g) content followed by (6.68 mg/100g) S_1P_6 (acetone at pH 6).

Table 4.26a Effect of pH and solvents on peel extracts from Day-1-5

Treatments	Day-1			Day-2			Day-3			Day-4			Day-5		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
S_1	21.52	25.41	23.46	13.74	13.88	13.81	12.53	13.26	12.90	10.48	10.27	10.38	8.36	7.79	8.07
S_2	40.65	23.07	31.86	46.51	20.33	33.42	43.62	25.99	34.80	21.76	13.22	17.49	22.96	13.00	17.48
S_3	34.99	34.44	34.71	29.51	30.48	29.99	24.06	20.80	22.43	24.79	23.92	24.35	21.92	22.87	22.39
S Em±	0.74	1.29	1.15	0.40	0.70	0.78	0.52	0.80	0.78	0.37	0.69	0.64	0.62	0.79	0.98
CD at 5%	2.22	3.86	3.46	1.22	2.10	2.35	1.57	2.41	2.43	1.13	2.08	1.94	1.85	2.38	2.94
P_1	31.25	26.68	28.96	30.92	22.79	26.86	26.90	22.56	24.73	20.23	15.95	18.09	15.45	12.89	14.17
P_3	30.12	28.26	29.19	34.36	23.24	28.80	30.77	22.43	26.60	21.56	19.29	20.43	16.09	19.97	18.03
P_6	32.80	27.97	30.38	24.48	18.67	21.57	22.54	15.05	18.80	15.24	12.17	13.70	10.70	10.80	10.75
S Em±	0.87	1.3	1.23	0.48	1.60	0.40	0.45	1.20	0.69	0.40	0.36	0.26	0.23	0.98	0.55
CD at 5%	NS	NS	4.43	1.45	0.55	1.19	1.36	3.8	2.08	1.20	1.09	0.78	0.71	2.94	1.66

4.3.1.6 Day-6

Different solvents at different pH levels combination adopted during the experiment showed significant difference in both the years (Table 4.26b). The maximum pigment content (17.90 mg/100g) was recorded in S_2 (methanol) and minimum (6.58 mg/100g) in S_1 (acetone). Data on different levels of pH showed significant difference on betacyanin pigment content in peel. The highest pigment content (17.01 mg/100g) was recorded at P_3 (pH 3) and lowest (10.03 mg/100g) at P_6 (pH 6).

The pooled data pertaining to the interaction effect of different solvents at different pH levels indicated that there is a significant variation noticed among the treatments during both the years (2021 and 2022) (Fig 4.9). The highest (23.54 mg/100g) betacyanin content was recorded in the treatment S_3P_3 (distilled water at pH 3) and the lowest (5.83 mg/100g) values were recorded under S_1P_1 (acetone at pH 1).

4.3.1.7 Day-7

The data on stability of betacyanin pigment as influenced by different solvents and levels of pH was recorded and presented in table 4.26b.

Individual effect of different solvents at different pH levels showed significant effect on the stability of betacyanin pigment. The pooled data also showed that there is a significant variation. The highest extraction (17.43 mg/100g) was recorded in S_3 (distilled water) and lowest (6.89 mg/100g) in S_1 (acetone). Data on the different pH levels showed highest betacyanin content was recorded at pH_3 (16.76 mg/100g) and lowest at pH_6 (10.20 mg/100g).

The pooled data pertaining to the interaction effect of different solvents at different pH levels are presented in table 4.26b and Fig 4.9 and results indicated that there is a significant variation noticed among the treatments during both the years (2021 and 2022). The highest (21.18 mg/100g) betacyanin content was recorded in the treatment S_3P_3 (distilled water at pH 1) and the lowest (5.17 mg/100g) values were recorded under S_1P_6 (acetone at pH 6).

4.3.1.8 Day-8

Data in table 4.26b showed that betacyanin pigment content in peel was influenced by different pH levels and solvents. The pooled data showed that the different solvents had significant effect on the betacyanin content in peel and same with different levels of pH. The highest pigment content (18.64 mg/100g) was recorded in S_3 (distilled water) and lowest (7.30 mg/100g) in S_1 (acetone).

Similarly, data on betacyanin pigment concentration in peel was influenced by different levels of pH. The maximum (16.79 mg/100g) was recorded in P_3 (pH 3) and the minimum (10.33 mg/100g) recorded in P_6 (pH 6).

The data pertaining to the interaction effect on different solvents and levels of pH on betacyanin content in peel of dragon fruit are presented in table 4.26b and Fig 4.9. The results indicated that the maximum pigment content (22.64 mg/100g) was recorded under the treatment S_3P_3 (distilled water at pH 3) and minimum (5.15 mg/100g) under S_1P_1 (acetone at pH 3).

4.3.1.9 Day-9

The perusal of data given in table 4.26b shows that extraction from various solvents at different levels of pH significantly influenced the betacyanin content in the peel of red dragon fruit. The pooled data of the year 2021 and 2022 resulted maximum pigment content (17.13 mg/100g) in the treatment S_3 (distilled water) and minimum in S_1 (5.78 mg/100g).

Different levels of pH had significant effect on the betacyanin content in peel of *Hylocereus polyrhizus*. The highest (14.49 mg/100g) was recorded at pH 3 and the lowest (8.11 mg/100g) at P_6 (pH 6).

The data on interaction effect of solvents at different pH levels revealed significant variation on Day -9 (Fig 4.9). Pooled analysis of data revealed that the highest betacyanin pigment concentration in peel (19.33 mg/100g) was recorded in the treatment S_3P_3 (distilled water at pH 3) and lowest (4.26 mg/100g) in S_1P_6 (acetone at pH 6).

4.3.1.10 Day-10

Data in table 4.26b showed that the betacyanin pigment content in peel was influenced by different pH levels and solvents. The pooled data showed that the different solvents had significant effect on the betacyanin content in peel and same with different levels of pH. The highest pigment content (14.03 mg/100g) was recorded in S_3 (distilled water) and lowest (7.97 mg/100g) in S_1 (acetone).

Similarly, data on betacyanin pigment concentration in peel was influenced by different levels of pH. The maximum (13.42 mg/100g) was recorded in P_3 (pH 3) and the minimum (7.16 mg/100g) recorded in P_6 (pH 6).

The data pertaining to the interaction effect on different solvents and levels of pH on betacyanin content in peel of dragon fruit are presented in Fig 4.9 and results indicated that maximum pigment content (17.00mg/100g) was recorded under the treatment S_3P_3 (distilled water at pH 3) and minimum (6.35 mg/100g) under S_1P_1 (acetone at pH 1).

The betacyanin content in the peel of dragon fruit stored for 10 days revealed that the initial extraction (Day-1) was high when distilled water was used as solvent at pH 1 and methanol at pH 6 was found at par with it meanwhile acetone at pH 6 recorded the least extraction. Methanol at pH 6 and pH 3 gave the highest extraction on Day-2 and Day-3 but from Day-4 to Day-10 distilled water at pH 3 was recorded highest extraction and methanol was found at par with it. Acetone recorded the lowest extraction when compared with other two solvents. From the above results it can be stated that the betacyanin extracted with either distilled water or methanol gave similar results initially (with slight variation) but pigment remained stable till tenth day in the samples where distilled water was used as solvent. Tang and Norziah (2007)

Table 4.26b Effect of pH and solvents on peel extracts from Day 6-10

Treatments	Day-6			Day-7			Day-8			Day-9			Day-10		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
S_1	6.43	6.73	6.58	6.86	6.92	6.89	7.00	7.61	7.30	6.11	5.44	5.78	7.33	8.62	7.97
S_2	24.60	11.20	17.90	23.45	8.70	16.08	19.75	12.80	16.28	17.06	8.88	12.97	15.33	7.11	11.22
S_3	17.42	15.08	16.25	19.97	14.89	17.43	18.51	18.77	18.64	19.73	14.52	17.13	17.69	10.37	14.03
S Em±	0.67	0.74	1.11	0.69	0.50	0.76	0.66	0.49	0.85	0.54	0.51	0.72	0.69	0.37	0.73
CD at 5%	2.01	2.23	3.34	2.10	1.51	2.28	1.99	1.48	2.55	1.64	1.52	2.18	2.07	1.12	2.19
P_1	18.17	9.23	13.70	17.30	9.57	13.43	17.55	12.64	15.09	17.12	9.37	13.27	15.81	9.48	12.64
P_3	19.28	14.73	17.01	19.52	13.9	16.76	17.23	16.35	16.79	16.74	12.25	14.49	17.55	9.29	13.42
P_6	11.00	9.05	10.03	13.46	6.95	10.20	10.48	10.18	10.33	09.00	07.23	8.11	6.98	7.34	7.16
S Em±	0.87	0.98	0.79	0.70	0.55	0.48	0.45	0.34	0.33	0.55	0.45	0.27	0.32	0.73	0.41
CD at 5%	2.61	2.95	2.37	2.11	1.66	1.45	1.37	1.01	0.99	1.65	1.36	0.83	0.98	NS	1.23

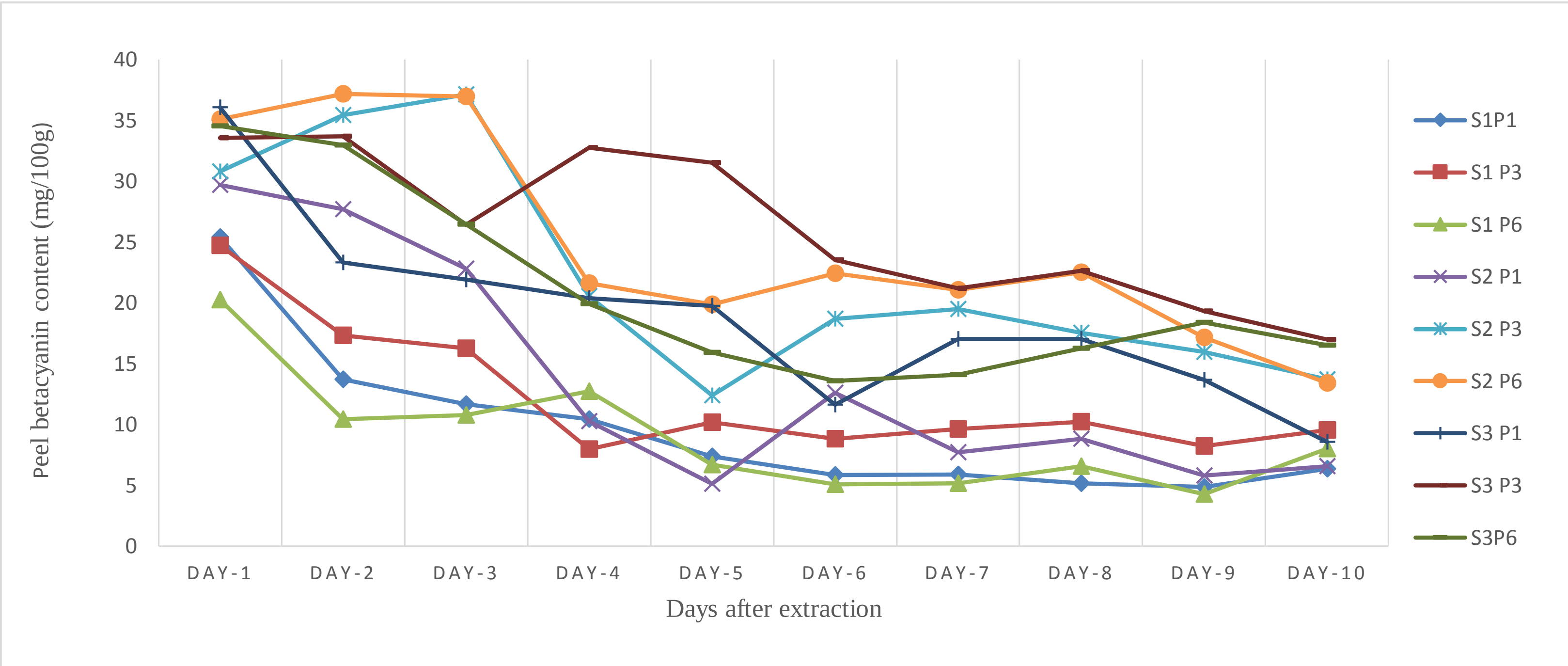


Fig 4.9 Interaction effect of pH and solvents on betacyanin content of *Hylocereus polyrhizus* peel extracts

reported related results in *Hylocereus polyrhizus* pulp. The results were in conformity with Castellar *et al.* (2006) who stated that the better extraction of betalin in opuntia fruit is by using water as a solvent. This might be due to the fact that the water is considered as high polar solvent followed by methanol and acetone. Due to the high molar absorbency index betacyanin is more soluble in water compared to non-polar solvents hence making water as a suitable solvent for extraction (Strack *et al*., 2003). Similarly, the pigment remained stable at pH range of 3 and 6 till the tenth day. The results are in conformity with Woo *et al*. (2011) who stated that betacyanin exhibited stability at the pH range of 3, 5 and 7 and Valliant *et al*. (2005) reported that pH 4-6 as optimal pH for betanin pigment stability.

The betacyanin content of the dragon fruit peel extracted by using acetone as a solvent was initially observed as pinkish purple in colour but it was found that there was a slight variation in the colour after the pH adjustment. The samples at pH 1 turned darker compared to the initial sample and samples at pH 3 and pH 6 turned to reddish pink in colour. Slight variation in the colour of samples was found when methanol was used as solvent and no variation was found with distilled water. After ten days of storage the betacyanin colour got degraded and turned yellow to green in colour. Samples extracted with acetone were found completely degraded at pH 1 and pH 6 and samples extracted with methanol also showed loss in colour and left with a tinge of orange. In contrary to the above solvents distilled water at pH 1 and pH 3 retained purple colour even after ten days of storage and complete change in colour was observed at pH 6 indicating that betacyanin pigment is stable at acidic conditions (Woo *et al.,* 2011) The degradation of the pigment might be due to the influence of different pH ranges which undergoes dehydrogenation, C_{15} isomerization (Stintzing and Clare, 2007; Azeredo, 2009). Degradation in the colour might also be due to the cleavage in the bond of nitrogen atom, dehydrogenation in carboxyl group and deglycosylation (Herbach *et al.,* 2006).

4.3.2 Effect of pH and solvents on pulp extracts

4.3.2.1 Day-1

The data on stability of betacyanin pigment in the pulp of dragon fruit as influenced by different solvents and levels of pH was recorded and presented in table 4.27a.

The effect of pH and solvents on betacyanin pigment content in pulp of dragon fruit was found significantly varied in the year 2021 and non-significant in 2022. From the pooled data it was observed that the maximum betacyanin extraction (42.54 mg/100g) was recorded in S_2 (methanol) and minimum (20.71 mg/100g) in S_1 (acetone). The results on different pH levels showed maximum betacyanin content (34.55 mg/100g) was recorded at pH_3 and lowest at pH_6 (31.78 mg/100g).

The interaction effect between different solvents and pH showed significant variation with respect to betacyanin content of pooled data. Treatment S_2P_6 recorded significantly highest betacyanin content (43.41 mg/100g) followed by S_2P_3 (43.33 mg/100g) whereas lowest (19.00 mg/100g) was recorded in S_1P_6 (Fig 4.10).

4.3.2.2 Day-2

The perusal of data given in table 4.27a showed that the extraction from various solvents at different levels of pH significantly influenced the betacyanin content in the pulp of red dragon fruit. The pooled data of the years 2021 and 2022 resulted maximum pigment content (39.18 mg/100g) in the treatment S_2 (methanol) and minimum in S_1 (18.56 mg/100g).

Different levels of pH had significant effect on the betacyanin content in pulp of *Hylocereus polyrhizus*. The highest (34.13 mg/100g) was recorded at pH 3 and the lowest (25.22 mg/100g) at P_1 (pH 1).

The data on interaction effect of solvents at different pH levels revealed significant variation on Day -2 (Fig 4.10). Pooled analysis of data revealed that the highest betacyanin pigment concentration in pulp (44.65 mg/100g) was recorded in the treatment S_2P_3 (methanol at pH 3) and lowest (16.24 mg/100g) in S_1P_1 (acetone at pH 1).

4.3.2.3 Day-3

Experimental results in table 4.27a indicated that there was a significant variation for betacyanin content in pulp of dragon fruit when extracted with different solvents at different pH levels. Among different treatments, on Day-3, distilled water (S_3) gave maximum extraction of betacyanin pigment in pulp (34.13 mg/100g) and minimum (13.90 mg/100g) by acetone (S_1).

Data on different levels of pH showed significant difference for betacyanin content in pulp of *Hylocereus polyrhizus*. The maximum pigment content (31.31 mg/100g) was recorded at pH_6 and minimum (21.57 mg/100g) at $pH_{1.}$

Interaction effect between solvents and pH levels combination significantly varied at storage. On Day-3 the highest betacyanin content in pulp (41.19 mg/100g) was recorded in the treatment S_3P_6 (distilled water at pH 6). Whereas S_1P_3 (acetone at pH 3) recorded lowest betacyanin (10.39 mg/100g).

4.2.2.4 Day-4

The data on stability of betacyanin pigment in pulp of dragon fruit as influenced by different solvents and levels of pH was recorded and presented in table 4.27a. Individual effect of different solvents at different pH levels showed significant effect on the stability of betacyanin pigment. The pooled data also showed that there is a significant variation. The highest extraction (35.13 mg/100g) was recorded in S_3 (distilled water) and lowest (8.76 mg/100g) in S_1 (acetone). Data on the different pH levels showed highest betacyanin content was recorded at pH_3 (23.63 mg/100g) and lowest at pH_6 (14.36 mg/100g).

The pooled data pertaining to the interaction effect of different solvents at different pH levels is presented in Fig 4.10. The results indicated that there was a significant variation noticed among the treatments during both the years

(2021 and 2022). The highest (41.96 mg/100g) betacyanin content was recorded in the treatment S_3P_6 (distilled water at pH 6) and the lowest (8.05 mg/100g) values were recorded under S_1P_1 (acetone at pH 1).

4.3.2.5 Day-5

Data in table 4.27a showed that the betacyanin pigment content in pulp was influenced by different pH levels and solvents. The pooled data showed that the different solvents had significant effect on the betacyanin content in peel and same with different levels of pH. The highest pigment content (32.51 mg/100g) was recorded in S_3 (distilled water) and lowest (9.78 mg/100g) in S_1 (acetone).

Similarly, data on betacyanin pigment concentration in pulp was influenced by different levels of pH. The maximum (22.26 mg/100g) was recorded in P_3 (pH 3) and the minimum (12.72 mg/100g) recorded in P_1 (pH 1).

The data pertaining to the interaction effect on different solvents and levels of pH on betacyanin content in pulp of dragon fruit are presented in Fig 4.10. The results indicated that the maximum pigment content (39.84 mg/100g) was recorded under the treatment S_3P_6 (distilled water at pH 6) and minimum (07.07 mg/100g) under S_1P_6 (acetone at pH 6).

4.3.2.6 Day-6

Data in table 4.27b showed that betacyanin pigment content in pulp was influenced by different pH levels and solvents. The pooled data showed that the different solvents had significant effect on the betacyanin content in pulp and same with different levels of pH. The highest pigment content (29.41 mg/100g) was recorded in S_3 (distilled water) and lowest (5.70 mg/100g) in S_1 (acetone).

Table 4.27a Effect of pH and solvents on pulp extracts from Day 1-5

Treatments	Day-1			Day-2			Day-3			Day-4			Day-5		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
S_1	19.59	21.84	20.71	18.35	18.77	18.56	13.42	14.38	13.90	8.48	9.04	8.76	9.99	9.56	9.78
S_2	48.83	36.25	42.54	47.27	31.09	39.18	36.86	24.87	30.86	20.03	15.02	17.53	15.60	15.39	15.50
S_3	35.70	36.53	36.12	29.65	31.69	30.67	32.92	35.33	34.13	34.20	36.06	35.13	32.04	32.99	32.51
S Em±	0.90	1.01	1.21	0.56	0.44	0.49	0.52	0.86	0.90	0.73	0.61	0.93	0.62	0.49	0.55
CD at 5%	2.71	3.04	3.62	1.69	1.33	1.48	1.58	2.59	2.17	2.18	1.84	2.81	1.87	1.47	1.67
P_1	34.77	31.30	33.04	27.83	22.6	25.22	23.81	19.33	21.57	13.59	15.13	14.36	13.03	12.41	12.72
P_3	36.76	32.34	34.55	37.31	30.9	34.13	28.82	23.20	26.01	23.27	23.99	23.63	22.82	21.70	22.26
P_6	32.59	30.97	31.78	30.13	27.9	29.06	30.57	32.05	31.31	25.85	21.00	23.43	21.80	23.82	22.81
S Em±	0.78	0.57	0.40	0.59	0.92	0.57	0.28	0.93	0.49	0.75	0.50	0.47	0.25	0.87	0.45
CD at 5%	2.33	NS	1.19	1.77	2.7	1.72	0.85	2.80	1.46	2.24	1.51	1.41	0.76	2.63	1.36

Similarly, data on betacyanin pigment concentration in pulp was influenced by different levels of pH. The maximum (23.06 mg/100g) was recorded in P_6 (pH 6) and the minimum (9.93 mg/100g) recorded in P_1 (pH 1).

The data pertaining to the interaction effect on different solvents and levels of pH on betacyanin content in pulp of dragon fruit was presented in Fig. 4.10. The results indicated that the maximum pigment content (37.25 mg/100g) was recorded under the treatment S_3P_6 (distilled water at pH 6) and minimum (5.54 mg/100g) under S_1P_1 (acetone at pH 1).

4.3.2.7 Day-7

Extraction of betacyanin pigment by different solvents at different pH level combination adopted during the experiment showed significant difference in both the years as well as in pooled data (Table 4.27b). The maximum pigment content (28.14 mg/100g) was recorded in S_3 (distilled water) and minimum (6.26 mg/100g) in S_1 (acetone). Data on different levels of pH showed significant difference on betacyanin pigment content in pulp. The highest pigment content (22.06 mg/100g) was recorded at P_6 (pH 6) and lowest (8.50 mg/100g) at P_1 (pH 1).

The pooled data pertaining to the interaction effect of different solvents at different pH levels indicated that there was a significant variation noticed among the treatments during both the years (2021 and 2022). The highest (38.01 mg/100g) betacyanin content was recorded in the treatment S_3P_6 (distilled water at pH 6) and the lowest (5.70 mg/100g) values were recorded under S_2P_1 (methanol at pH 1).

4.3.2.8 Day-8

Data in table 4.27b showed that the betacyanin pigment content in pulp was influenced by different pH levels and solvents. The pooled data showed that the different solvents had significant effect on the betacyanin content in pulp and same with different levels of pH. The highest pigment content (29.67

mg/100g) was recorded in S_3 (distilled water) and lowest (8.63 mg/100g) in S_1 (acetone).

Similarly, data on betacyanin pigment concentration in pulp was influenced by different levels of pH. The maximum (22.88 mg/100g) was recorded in P_6 (pH 6) and the minimum (9.62 mg/100g) recorded in P_1 (pH 1).

The data pertaining to the interaction effect on different solvents and levels of pH on betacyanin content in pulp of dragon fruit are presented in Fig 4.10. The results indicated that the maximum pigment content (38.57 mg/100g) was recorded under the treatment S_3P_6 (distilled water at pH 6) and minimum (5.60 mg/100g) under S_2P_1 (methanol at pH 1).

4.3.2.9 <u>Day-9</u>

Experimental results in table 4.27b indicated that there was a significant variation for betacyanin content in pulp of dragon fruit when extracted with different solvents at different pH levels. Among different treatments, on Day-9, distilled water (S_3) gave maximum extraction of betacyanin pigment in pulp (26.32 mg/100g) and minimum (5.65 mg/100g) by acetone (S_1).

Data on different levels of pH showed significant difference for betacyanin content in pulp of *Hylocereus polyrhizus*. The maximum pigment content (19.25 mg/100g) was recorded at pH_6 and minimum (6.70 mg/100g) at $pH_{1.}$

Interaction effect between solvents and pH levels combination significantly varied at storage. On Day-9 the highest betacyanin content in pulp (36.85 mg/100g) was recorded in the treatment S_3P_6 (distilled water at pH 6). Whereas S_2P_1 (methanol at pH 1) recorded lowest betacyanin (3.66 mg/100g).

4.3.2.10 <u>Day-10</u>

Data in table 4.27b showed that the betacyanin pigment content in pulp was influenced by different pH levels and solvents. The pooled data showed that the different solvents had significant effect on the betacyanin content in pulp and same with different levels of pH. The highest pigment content (21.62

mg/100g) was recorded in S_3 (distilled water) and lowest (6.16 mg/100g) in S_1 (acetone).

Similarly, data on betacyanin pigment concentration in pulp was influenced by different levels of pH. The maximum (15.78 mg/100g) was recorded in P_6 (pH 6) and the minimum (6.97 mg/100g) was recorded in P_1 (pH 1).

The data pertaining to the interaction effect on different solvents and levels of pH on betacyanin content in pulp of dragon fruit was presented in Fig 4.10. The results indicated that the maximum pigment content (30.00 mg/100g) was recorded under the treatment S_3P_6 (distilled water at pH 6) and minimum (4.48 mg/100g) under S_2P_1 (methanol at pH 1).

The betacyanin content in the dragon fruit pulp stored for 10 days revealed that the initial extraction (Day-1) was highest when methanol was used as solvent at pH 6 and pH 3 was found at par with it meanwhile acetone at pH 6 recorded the least extraction. On Day-2 methanol at pH 3 gave the highest extraction. However, from Day-4 to Day-10, distilled water at pH 6 has recorded highest extraction while acetone recorded the lowest extraction when compared with other solvents. From the above results it can be stated that the betacyanin extracted with methanol gave best results initially but the pigment remained more stable in the sample's where distilled water was used as solvent. This might be due to the fact that water has high polarity compared to methanol and acetone due to its molecular structure and properties. Water having high polarity and strong hydrogen bonding capability makes an excellent solvent for betacyanin pigment. Similarly, the pigment remained stable at pH 3 and pH 6 till the tenth day. The betacyanin content in pulp recorded highest values compared to peel. The results are in conformity with Razak *et al*. (2017) and Tang *et al.* (2007).

Table 4.27b Effect of pH and solvents on pulp extracts from Day 6-10

Treatments	Day-6			Day-7			Day-8			Day-9			Day-10		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
S_1	5.14	6.26	5.70	5.90	6.61	6.26	8.19	9.07	8.63	5.54	5.76	5.65	5.93	6.46	6.16
S_2	19.76	10.77	15.27	16.16	8.67	12.41	17.55	12.24	14.90	10.73	8.34	9.53	7.55	7.33	7.61
S_3	29.65	29.17	29.41	28.51	27.77	28.14	29.14	30.20	29.67	26.13	26.52	26.32	21.14	5.38	21.62
S Em±	0.63	0.75	0.74	0.62	0.62	0.68	0.60	0.34	0.52	0.62	0.53	0.60	0.58	0.44	0.49
CD at 5%	1.88	2.25	2.21	1.87	1.86	2.06	1.81	1.04	1.57	1.85	1.58	1.81	1.76	1.33	1.47
P_1	10.33	9.53	9.93	9.03	7.98	8.50	8.72	10.53	9.62	6.61	6.80	6.70	6.11	7.82	6.97
P_3	19.15	15.62	17.39	16.81	15.70	16.25	22.24	19.15	20.69	15.77	15.32	15.55	11.76	13.52	12.64
P_6	25.07	21.05	23.06	24.74	19.37	22.06	23.93	21.84	22.88	20.01	18.50	19.25	16.75	14.81	15.78
S Em±	1.07	0.77	0.54	0.41	0.72	0.36	0.30	0.67	0.34	0.34	065	0.31	0.18	0.67	0.33
CD at 5%	3.22	2.30	1.63	1.23	2.15	1.08	0.92	2.02	1.04	1.04	1.96	0.92	0.54	2.03	1.01

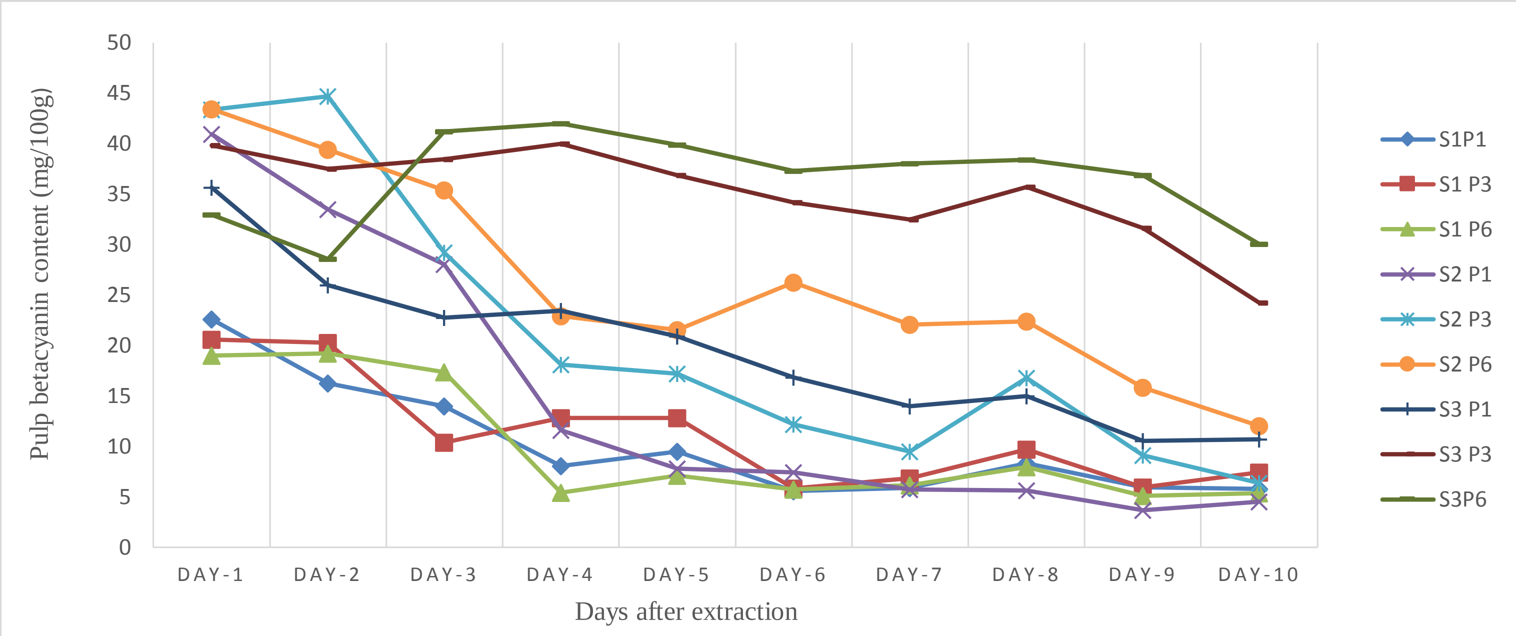


Fig 4.10 Interaction effect of pH and solvents on betacyanin content of *Hylocereus polyrhizus* pulp extracts

Similar to the peel colour observations the betacyanin content of pulp extracted by using acetone as a solvent was initially observed as pinkish purple in colour. However, a slight variation in the colour was found after pH adjustment. The samples at pH 1 appeared darker compared to the initial sample and samples at pH 3 and pH 6 turned to reddish pink in colour. Dark purple colour at pH 1 was recorded when methanol was used as solvent while the other two samples at pH 3 and pH 6 changed to reddish pink in colour. In contrary to the observations recorded in peel after the pH adjustment, the betacyanin content in pulp extracted with distilled water at pH 1 turned to dark purple colour and samples at pH 3 and pH 6 remained unchanged. After a storage period of ten days the degradation in the colour of samples occurred. Woo *et al*. (2011) reported that there was 80 to 90% change in colour after one week of storage. Degradation of colour occurred after two days of storage in red beet (Reynoso *et al.*, 1997). Samples extracted with acetone were found completely degraded at pH 1, 3 and 6 and those with methanol showed loss in colour with a tinge of orange. Contrary to the above solvents distilled water at pH 1, 3 and 6 retained purple colour even after ten days of storage. The colour retention might be due to the fact that betacyanin is water soluble due to its chemical structure where interaction occurs between polar groups and water molecules through hydrogen bonding thus making water as a suitable solvent for pigment extraction. Lim *et al*. (2011) stated that though betacyanin displays broad pH range from 3 to 7 it was found that pH 6 was considered as the optimum pH for stability of betacyanin pigment.

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

The results of investigation entitled "Phenological studies on dragon fruit (*Hylocereus polyrhizus*) in response to nitrogen and agro-ecological conditions of Nagaland" carried out during the year of 2021 and 2022 was conducted in the experimental farm of Department of Horticulture, School of Agricultural Sciences, Medziphema Campus, Nagaland are summarized below:

Experiment I Nitrogen sources on growth and development

There were significant variations on the growth and flowering of the different treatments as compared to control. Maximum cladode length, cladode diameter, girth and number of areoles/cladodes were recorded with the treatment 75% of N_{150g}+Pig $manure_{2.5\ kg}$ /plant (T_{10}). The distance between areoles and area of areoles were also recorded highest with this treatment. Similarly, maximum flower length, fruit weight, fruit length, fruit width and peel weight resulted with application of 75% of N_{150g}+Pig $manure_{2.5\ kg}$ /plant (T_{10}) closely followed by treatment of 75% of N_{125g}+Pig manure $_{2.1\ kg}$/plant (T_9) which were found to be statistically at par in these fruit characteristics.

The maximum TSS was recorded in the treatment 75% of N_{100g}+Pig $manure_{1.66\ kg}$/plant (T_8), whereas reducing and total sugars were recorded maximum with 75% of N_{150g}+$FYM_{1.5\ kg}$/plant (T_7). The ascorbic acid content, betacyanin content in peel and pulp of dragon fruit were recorded highest in the treatment 75% of N_{125g}+FYM $_{1.25\ kg}$/plant (T_6). The phenolic content in peel was recorded maximum in the treatment N_{150g}/plant (T_4) whereas 75% of N_{150g}+ Pig $manure_{2.5\ kg}$/plant (T_{10}) recorded maximum phenolic content in the pulp. Treatment with 75% of N_{150g}+Pig $manure_{2.5\ kg}$/plant (T_{10}) recorded maximum content of available nitrogen and phosphorus in soil whereas potassium was found highest with 75% of N_{150g}+$FYM_{1.5\ kg}$/plant (T_7) and N_0 (Control) recorded the minimum nitrogen, phosphorous and N_{150g}/plant (T_4) recorded minimum K content in soil. Analyses of cladodes revealed that treatment with 75% of N_{150g} + Pig manure $_{2.5\ kg}$/plant (T_{10}) recorded maximum nitrogen content whereas 75% of N_{125g}+Pig manure$_{2.1kg}$/plant (T_9) recorded maximum phosphorus and potassium content while minimum N and K were recorded in N_0 (Control) and P with treatment of $N_{150g/}$plant (T_4).

Experiment II Phenology studies

Studies on phenology of flowering, fruiting and biochemical attributes of *Hylocereus polyrhizus* was conducted and correlated with the weather parameters. The peak flowering season in the first year (2021) was recorded from June to August with few flowerings extending up to September and for the year 2022, the peak flowering season occurred from May to August, which continued up to October. The peak flowering time in the year 2021 was recorded between 10:00 pm to 12:00 pm and from 9:00 pm to 11:00 pm in 2022. The number of days taken form bud to flowering was recorded as 15.32 to 20.35 and number of days taken from anthesis to fruit ripening as 29.50 to 36.10. The fruiting season of dragon fruit in mid-hill conditions of Nagaland was observed from May to September and sometimes continued till October. The flowers of dragon fruit were found to be hermaphrodite, bracteolate, actinomorphic, consisting bracts, epigynous, with numerous apostemonous stamens and basifixed anthers, tubular style, unilocular ovary with numerous corolla and calyx. The fruit was medium to large in size, round to oblong in shape with pink colour flesh and numerous black seeds scattered inside the pulp. The flower, fruit and biochemical attributes varied within the following range: flower length (25.48 to 30.03 cm), petal length (10.65 to 12.51 cm), petal number (20.47 to 23.73), style length (11.24 to 14.50 cm), stamen length (7.26 to 11.54 cm), stigma lobe length (1.61 to 2.66 cm), number of stigma lobes (24.37 to 34.00), pericarp length (12.06 to 14.82 cm), perianth length (13.54 to 16.25 cm), distance between anther to stigma (0.63 to 1.63 cm), days taken from anthesis to fruit ripening (29.00 to 36.50), fruit length (6.23 to 9.19 cm), width (6.75 to 8.59 cm), fruit weight (184.00 to 441.00 g), pulp weight

(118.00 to 337.00 g), peel thickness (1.77 to 3.86 mm), peel weight (60.30 to 97.60 g), pulp percentage (63.12 to 78.14 cm), TSS (12.50 to 16.30 °Brix), acidity (0.21 to 0.10 %), TSS/acid (59.52 to 142.10), reducing sugars (3.89 to 6.98 %), total sugars (6.05 to 8.40 %), non-reducing sugars (0.19 to 4.30 %), ascorbic acid (2.52 to 3.45 mg/100g), peel phenolic content (38.10 to 59.50 mg/100g), pulp phenolic content (41.80 to 52.00 mg/100g), peel betacyanin content (21.88 to 41.74 mg/100g) and pulp betacyanin content (21.34 to 39.35 mg/100g). The days taken from bud to flower opening, days taken from anthesis to fruit ripening, TSS, TSS/ acid, total sugars, pulp and peel betacyanin content had positive correlation with temperature. Fruit weight and fruit length had positive correlation with relative humidity whereas flower length, petal length, fruit weight, length, width, pulp weight, peel weight and pulp % had positive correlation with rainfall whereas TSS, reducing sugars and total sugars had negative correlation with rainfall.

Experiment III Betacyanin stability studies

Nine treatments with three different solvents (acetone, methanol and water) and pH (1, 3, and 6) was designed to evaluate the maximum extraction and stability of betacyanin pigment from both peel and pulp of dragon fruit. The different solvents at different pH levels and their interaction effect had significant influence on betacyanin content in both peel and pulp. On Day-1 the betacyanin pigment extracted from peel of *H. polyrhizus* by using distilled water at pH 3 showed highest pigment concentration compared to other solvents whereas methanol recorded highest betacyanin content in the pulp at pH 3. Though the pigment concentration in pulp varied initially, on Day-5 the pigment extraction was found maximum in distilled water at pH 3, which was found to be statistically at par with pH 6. Methanol had the maximum extraction of betacyanin content form pulp of dragon fruit initially but decreased gradually after continuous monitoring for the period of 10 days whereas extraction from distilled water was stable even after 10 days of storage. Betacyanin pigment content in peel remained more stable when extracted by using distilled water till Day-10 at pH 3. The pigment content in pulp was recorded higher than in the peel. The interaction effect of pooled data for peel at Day-1 showed that, S_3P_1 (Distilled water at pH 1) recorded highest betacyanin content (36.05 mg/100g) initially but with progress in days, pigment was found to be more stable at S_3P_3 (Distilled water at pH 3) compared to other treatments. In fruit pulp, $S_2 P_6$ (Methanol at pH 6) recorded highest betacyanin content initially, but with progress in days the pigment stability was observed with the treatment S_3P_6 (Distilled water at pH 6). Out of all the solvents considered in this experiment, acetone showed least pigment extraction of the pigment.

Based on the above summary of the results, the following conclusions may be drawn from the present investigation:

- The results of the two consecutive years revealed that the combined application of 2.5 kg pig manure with 75% of N_{150g} found to be most superior treatment combination with regard to vegetative growth, flowering and fruiting in *H. polyrhizus.*
- Qualitative characters of fruit were found to be better with application of 75% of N_{100g}+Pig manure$_{1.66\ kg}$/plant (T_8) and 75% of N_{150g}+ FYM$_{1.5\ kg}$/plant (T_7). The bioactive compounds such as ascorbic acid and betacyanin content in peel and pulp of dragon fruit were recorded highest in the treatment 75% of N_{125g}+FYM $_{1.25\ kg}$/plant (T_6). Integrated application of inorganic fertilizer along with any organic manure may be recommended to farmers for enhancing fruit quality in dragon fruit.
- *Hylocereus polyrhizus* cultivated in mid hill conditions of Nagaland started blooming in the month of May and continued till October and the peak flowering season was marked from May to August. Weather parameters like temperature and rainfall greatly influence flowering and fruiting of dragon fruit. Average number of days taken from bud

emergence to flower opening was recorded as 15-20 days and 29-36 days for fruit ripening from flower anthesis.

- Distilled water as a solvent at pH 3 for peel and pH 6 for pulp may be recommended for extraction and stability of betacyanin pigment for industrial use as natural pigment.

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