Field Assessments of Bell Pepper Varieties Produced in the Dry Zone of Sri Lanka

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Abstract- *Bell pepper is a high valued crop that is commonly grown in controlled environments in the wet and intermediate zones of Sri Lanka. However, lesser efforts have been made in evaluating the field performances in the dry zones, hence, this study aims to elucidate the field performances of three commercial elite varieties of bell pepper viz Ganga (green), Indra (red), and Polarized (yellow). The field experiments were carried out at Agrotech park, Malwatta in the Ampara district was laid out in a randomized complete block design with three replicates in each plot size of 2.25m x 2.25m. The plant morphological and fruit characteristics were analysed at the harvesting stage. The results showed that the variety Ganga (green) performed superior to the remaining two varieties as it possessed improved field plant survival rates (78.6 %), fruit set, and significantly improved the number of fruits (7 Nos/plant) hence, the overall highest number of yields per plant (394.6 g/plant). Therefore, this study hints that the farmers in the dry zone may cultivate successfully the green bell pepper varieties (var. Ganga) at home garden levels or as commercial cultivation in the open fields, which may serve as an alternative viable source of income than the conventional cash crops. Moreover, to confirm the quality of fruits produced in this region, further researches are needed to elucidate the fruit quality through sensory evaluations and fruit pericarp chemical compositions at laboratory levels.*

Keywords: Bell pepper, dry zone, open field, yield

I. INTRODUCTION

Bell pepper (*Capsicum annum* L.) belongs to the family Solanaceae and native to Mexico, Central and South America (Echer *et al*., 2002). The plant produces fruits in a variety of colours, including red, yellow, orange, green, white, and purple cultivars, and the fruits are botanically classified as berries. At present, the bell pepper is vastly produced in China, Mexico, Turkey, Indonesia, Spain and United States (FAOSTAT, 2017). In Sri Lankan context, the bell pepper is grown mostly in the intermediate and wet zone under the protected agricultural systems in polytunnel with the provision of drip irrigation combined with expensive Albert hydroponic solutions to promote quality and fruit yield. Therefore, this crop is recognized as a high valued crop as it requires expensive structural facilities with sophisticated set-ups to maintain the temperature within 21^{o} C to 25 ^{o} C (Department of Agriculture Sri Lanka (DOA), 2015), relative humidity(>70%), proper air circulation within the crop canopies and the optimal supply of nutrient solutions to the root zone. Locally, the bell pepper has an increasing demand and the extent of cultivation is rising in wet zones under the provision of such sophisticated plant growth conditions. In a recent study, it has been shown that the bell pepper was cultivated in 3,678 hectares and annual production was 32,309 Metric tons (Department of Census and Statistics, 2019). The fresh yellowish and greenish bell pepper have export potential in Sri Lanka. Therefore, it is considered one of the potential crops to boost the economic growth of the country.

The economically important part of this crop is demanded as a key ingredient for the preparation of premium foods like salads, stews, salsa, and pizzas etc. in star hotels and fast-food chains. Consumers prefer this fruit owing to its health benefits as the fruit contains vitamin A, vitamin C, potassium and a healthy dose of fibre, folate, and iron (Denev *et al.*, 2019). Further, the fruit is widely used for diverse applications as food additives, health and cosmetic products, pest control agents in agricultural fields, etc

The exploration of morphological characteristics is considered an important avenue to understanding the diversity among crops (Assefa *et al.*, 2014). In recent years, morphological characteristics of 25 genotypes of bell pepper have been investigated in the open field condition in dry zones of India (Sood, Sood and Vidyasagar, 2011) and reveal that diverse morphological variations were observed in plant growth and branching

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habit, fruit shape and colour. Moreover, phenotypic diversity and capsaicinoid content for nine chilli pepper landraces from the western Yucatan peninsula in Maxico is reported to show the diversity among landraces. (Castillo-Aguilar *et al.*, 2021). Similarly, the fruit characteristics of green, yellow and red varieties grown inside poly-tunnel were reported and seem to have significant morphological differences among capsicum species (Zhigila *et al*., 2014). Moreover, bell peppers have the potentials to grow organically, and a recent study revealed that composted farmyard manure treatment enhanced bell pepper growth and yield, as the application of organic matter improves soil properties (Gopinath *et al.*, 2009).

In this context, the dry zone of Sri Lanka has massive potentials for growing vegetables as this region contains a vast area of arable land with the availability of ample labour force compared to the other two regions. As outline earlier, bell pepper cultivation in polytunnels is largely ignored and a less popular crop in dry zones as the initial cost for constructing polytunnels are far expensive than conventional farming, non-affordable by a poor farmer, require sound technologies with efficient energy management strategies. Moreover, it is presumed that such high valued crops cannot be grown in the open fields and the predicted yield performance and quality of produces may be in a dilemma when the quality is concerned by local consumers and the food industries. Therefore, this research aims to explore the potentials for growing elite bell pepper varieties in the open fields and to systematically analyze the morphological and fruit characteristics produced such conditions in the Ampara district.

II. METHODOLOGY

A. Field Condition

A field trial was carried out between October 2018 to January 2019 at the Agro Tech Park, Malwatta (7°20'N and 81°44'E altitude 16.0 m above sea level) located in the Ampara district of Sri Lanka. Monthly average rainfall and temperature data were collected for five years (2012 to 2017) from the nearest metrological station at Pottuvil, Department of Metrology Sri Lanka Furthermore, Photo synthetically Active Radiation values (PAR) were recorded by employing an external light sensor of ceptometer (SC-1, Decagon Devices Inc, USA) throughout the trial period.

B. Field Establishment

Three varieties viz Ganga (green), Polarized (yellow), and Indra (red) of bell pepper plants (*Capsicum annuum L.*) were established in germination trays and maintained in propagators to ensure high humidity and optimal temperature to promote uniform germination. Then, seedlings were field transplanted at the six leaves stage with the spacing of 45 x 45 cm. The field experiment was laid out in randomized complete block design with three replicates containing each plot size of 2.25m x 2.25m. Then the standard agronomic practices of Chili recommended by DOA were practiced. Because there is no such recommendation has been released for open field bell pepper cultivation. Hence, the basal dressing was applied at the rates of 100kg/ha of P_2O_5, and 50 kg/ha of K_2O. Subsequently, applied urea as a top dressing in four splits at 2, 4, 8, and 12th weeks after field planting at a rate of 475kg/ha. In addition, MOP at the rate of 50 kg/ha was applied with the third top dressing. Plants were irrigated manually as per the crop requirement.

C. Data Collection

At the flowering stage, the plant height was measured using 1 mm least count measuring tape and the number of survived plants were counted in each plot. Subsequently, at post-flowering stage, five plants per treatment were randomly selected and following measurements were taken. (i) The number of productive branches based on the fruit set per branch (ii) at two-week interval, number of mature fruits and yield per plant.

Then the fruit characteristics at physiological maturity stage were collected. Twenty-five fruits of each variety were randomly selected from the harvest. Then individual weight of fruits was measured using 0.001 gram least count electronic digital balance. The longitudinal length of the fruit was measured using a 1 mm least count foot ruler. The fruit circumference was measured by tightly wrapping the fruit with a single strand thread, and then the actual length of tread was taken. Then the fruit was transversely cut opened to measure the pericarp thickness and the breadth, were measured by 0.02 mm least count veneer caliper. Finally, the number of lobes per fruit was counted. The collected data of each parameter were used to test their significant differences among the bell pepper varieties using SPSS statistical software. The hypothesis were statistically tested using one-way ANOVA with Tukey's post-hoc test at 5 % significant level.

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III. RESULTS AND DISCUSSION

A. Climatic Condition during Experimental Period

The natural weather condition during the experimental period (October 2018 to January 2019) is displayed in Table 01.

Table 01: Mean rainfall received and daily recorded temperature at Agro-Tech Park

Month	Rainfall (mm)			Temperature (^{0}C)		
	Mean ± SD	Min	Max	Mean ± SD	Min	Max
October	152.37 ± 82.01	12.80	249.50	32.51 ± 1.01	31.35	33.79
November	299.90 ± 144.13	84.30	496.80	30.77 ± 0.45	30.20	31.52
December	341.43 ± 210.19	39.40	658.90	29.95 ± 0.91	28.86	31.03
January	235.90 ± 184.84	7.00	433.90	29.96 ± 0.71	29.31	30.94

Table 02: Plant phenotypic characteristics of three bell pepper varieties

Characteristics		Indra (Red)	Polarized (Yellow)	Ganga (Green)	P - Value
	n	Mean ± SE	Mean ± SE	Mean ± SE	
Plant height (cm)	28	30.61 ± 1.55 ^{a}	32.07 ± 1.56 ^{a}	31.84 ± 0.91 ^{a}	0.721
Number of productive branches	28	6.93 ± 0.63 ^{a}	7.24 ± 0.52 ^{a}	7.09 ± 0.39 ^{a}	0.915
Seedling Survival Rate (%)	15	64.30 ± 7.82^a	57.14 ± 3.91^a	78.57 ± 8.14^b	0.048

The superscript with different letters indicates significant differences between bell pepper varieties (p-value < 0.05)

The average mean monthly rainfall was ranged from 152 – 235 mm, and temperature ranged from 30 – 32.5 ^{0}C respectively. This result reveals the experimental site was experiencing typical dry zone climatic conditions with intermitted rainfall. Through supplying the regular intervals of irrigation, crop water requirements can be substituted. Similarly, the high intensive solar radiation is another avenue to consider when open cropping is considered. Here, the average PAR value during the experimental period was 1856.4 µmol m^{-2} s^{-1} (Data is not shown) which may promote photosynthesis to a certain extent in crops. Though, the extreme levels of PAR can cause photo oxidative stress in crops. Hence, bell pepper varieties with improved physiological characteristics may perform well under high sunlight intensities.

B. Morphological Characteristics of Plants

Bell pepper seedling survival rate was assessed one month after field planting. The result revealed that the variety Ganga showed a significantly ($p<0.05$) higher survival rate (78%) whereas var. Polarized (yellow) and Indra (Red) displayed 58 % and 64 %, respectively (Table 02).

The mean plant height of each variety was ranging from 30 cm to 32 cm, and there were no significant differences seen among the three varieties. Moreover, the number of productive branches per plant showed insignificant differences among tested varieties (7 per plant). In previous open field studies, it has been noted that the bell pepper genotypes plant height varied from 31 to 70 cm whereby all genotypes produced were blocky shape fruits (Sood, Sood and Vidyasagar, 2011).

C. Fruit and yield characteristics

The fruit characteristics of all three bell pepper varieties were compared at their physiological maturity. The most important commercial trait for bell pepper relies on its fruit characteristics. Here, the variety Ganga possessed significantly higher ($p<0.05$) and had approximately 5 lobs per fruit compared to the remaining two varieties (Table 03). Conversely, fruit length had displayed insignificant differences. Interestingly, there were significant differences were seen for fruit circumferences and as for the fruit breadth. Variety Ganga produced the highest circumferences and (211.50 mm, $p<0.05$) and fruit breadth (64.36 mm) among the tested lines -

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Table 03: Fruit characteristics of three bell pepper varieties

Characteristics	Indra (Red)	Polarized (Yellow)	Ganga (Green)	P-Value
	Mean ± SE	Mean ± SE	Mean ± SE	
Number of lobs (locules)	3.8 ± 0.27 [a]	3.96 ± 0.23 [ab]	4.83 ± 0.29 [b]	0.023
Length (mm)	59.75 ± 2.07 [a]	60.22 ± 1.84 [a]	60.98 ± 1.76 [a]	0.899
Circumference (mm)	189.74 ± 5.08 [a]	197.40 ± 5.49 [ab]	211.67 ± 3.32 [b]	0.007
Breadth (mm)	56.64 ± 1.87 [a]	57.50 ± 1.77 [a]	64.36 ± 1.19 [b]	0.002
Weight (g/fruit)	67.95 ± 4.86 [a]	72.62 ± 4.93 [ab]	84.45 ± 3.76 [b]	0.037

The superscript with different letters indicates significant differences between bell pepper varieties (p-value < 0.05), (n = 5).

The pericarp of the fruit is a crucial parameter in determining fruits' pungency, taste, and crispiness. Moreover, it is more closely related to the fruit yield (Weryszko-chmielewska and Micha, 2011). In addition, the level of chemical composition and synthesis rates is determined by the pericarp thickness. Here, the variety Indra possessed the thickest pericarp while the green variety had displayed the second-highest thickness. The present study further revealed that the inverse relationship between pericarp thickness and the yield were observed.

In a previous study, the green, red, and yellow varieties' average fruit lengths were 71.36 mm, 42.35mm and 126.69 mm, respectively. Similarly, the corresponding average fruit breadth was 45.37 mm, 35.57 mm and 44.94 mm, respectively (Sood, Sood and Vidyasagar, 2011).

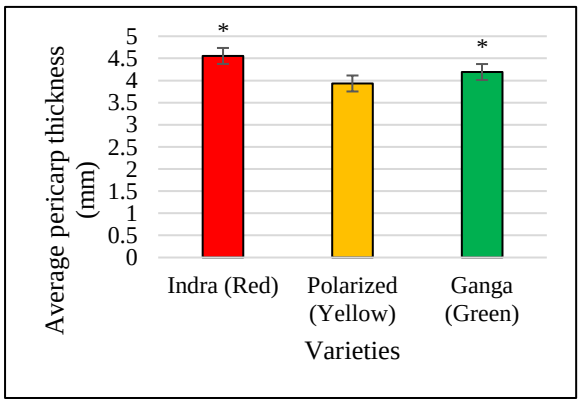

Figure 1: Pericarp thickness of three varieties of bell pepper fruits. The symbol (*) indicates significant differences between bell pepper varieties (p-value <0.05), (n=5)

Moreover, Ballina-Gómez *et al*., (2013) studied 47 morphological characteristics of bell pepper accessions grown in a controlled environment and reports that the optimized number of fruit locules (3 Nos) with fruit length (50 mm) and thickness (2.0 mm) is produced. These findings are in line with our present study emphasizing quality of filed grown bell pepper can be maintained.

The fruit yield was compared. It was observed that significantly ($p<0.05$) higher yield per plant was obtained in green varieties (394.6 g/plant). However, the yield of yellow and red plants was relatively lower in the open field conditions (Figure. 2). Similarly, the variety Ganga produced significantly ($p<0.05$) increased fruits weight (84.45g/fruit) than the counterparts, while the second-highest was seen in variety Polarized (72.6g/fruit) (Table 03). These findings elucidate, the Ganga bell pepper variety has the potential to grow in open fields of dry zones conditions, specifically in DL 2 band as it seems to possess fairly improved drought tolerance characteristics.

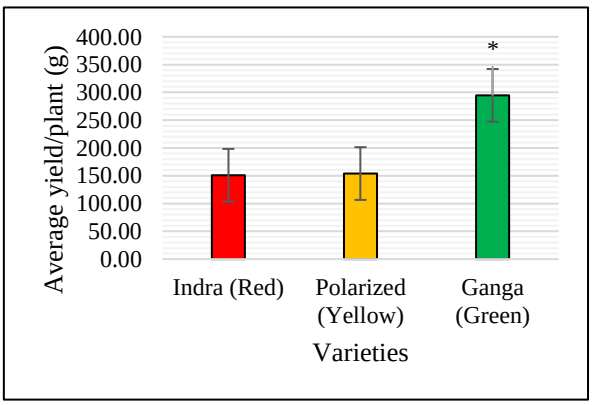

Figure 2: Average yield per plant of three bell pepper varieties. The symbol (*) indicates significant differences between bell pepper varieties (p-value <0.05), (n=5)

In a previous study conducted by Sood *et al.* (2009) reported that the bell pepper cultivated under an open field and humid temperate climatic condition, the green and yellow varieties yielded 336.5 g/plant and 222.3 g/plant, respectively. This shows that field-grown bell peppers particularly variety Ganga has the potential to produce acceptable fruit size and yield per plant compared

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to other varieties. This may contradict the observations that field-grown bell pepper produces relatively smaller fruits than that grown under optimally controlled polytunnel environments (Singh, Singh and Gupta, 2011).

Therefore, the above observation reported in the present experiment may be a result of variations in the genetic make-up of the tested varieties as most of the plant physiological characteristics are determined by dozens of genes. For the adaptation of dry zones, optimal leaf stomatal conductance and the presence of optimal cuticle wax on greener surfaces assist to maintain increased photosynthetic rates while to minimize water losses (transpiration). In recent studies, the studies with the green bell pepper varieties seem to possess more chloroplast in mitochondria than red and yellow fruits hence the metabolic enzyme in the peroxisome are high and respond positively in fruit quality (Palma *et al*., 2015). Similarly, it may also be speculated the leaf level mechanism may also be possible to minimize photooxidative stresses in the high performing bell pepper varieties. Moreover, drought resistance may also rely on root trait as well, deeper root systems with efficient absorption of water and nutrients have advantageous over the traits with shallow rooting systems. However, the present studies were not focused on these avenues to validate the predictions.

Fruit characters are been controlled by three to ten pairs of genes with a heritability value of 40 to 50 per cent in Capsicum (Zhigila *et al*., 2014). Moreover, the fruit traits might also have been the direct influence of agronomic practices and the prevalence of environmental conditions. Typically, bell pepper grown in increased humidity seems to produce succulent and larger fruit, while in this study, the green variety produced relatively larger and eye-appealing fruit characteristics compare to the other tested lines. This occurrence may have a direct impact on dry zone farmers that can speculate that bell peppers can be successfully grown under open fields in dry zones.

IV. CONCLUSION

Bell pepper is a high valued crop that is commonly grown in controlled environments in the wet and intermediate zones of Sri Lanka. Here, we showed that certain bell pepper varieties, in fact, can be successfully grown in open field condition in the dry zones of Sri Lanka with no detrimental impacts on either crop physiological processes or the fruit harvest. Although we applied minimal level of inexpensive fertilizer dosages while excluding the classical Albert hydroponic solution that ensures minimal impacts on environment. Hence, these observations have some profound implications for the local farmers. First, green bell pepper varieties (var. Ganga) can be successfully grown at home garden levels or be practiced as commercial farming in the dry zones, which may serve as an alternative crop for conventional cash crops such as chilli, okra, and brinjal. Second, there is an opportunity to improve the income of local farmers as the bell pepper offers premium prices than conventional cash crops. However, our researches have been limited to crop yield trials, though any future avenues in organic farming, sensory evaluations, assessing chemical composition of fruit pericarp produced in the dry zone will increase the promotion of bell pepper further.

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