

Optimization of Fertigation Levels and Storage Conditions for Enhancing Shelf Life in Bitter Gourd (*Momordica charantia* L.)

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Abstract

Improving post-harvest quality and shelf life in bitter gourd through precise fertigation strategies is critical for enhancing both marketability and consumer health benefits. The study was conducted to evaluate the shelf life of four bitter gourd hybrids, Prajani, Pragathi, Maya and Pusa Hybrid 4, under six different fertigation regimes: 75 % RDF, 100 % RDF, 125 % RDF, 150 % RDF, Package of Practice Recommendation and absolute control. Physiological loss in weight (PLW) was assessed under ambient and refrigerated storage conditions. The best outcome, with minimal PLW, was observed in fruits stored under refrigerated conditions and the hybrid Pragathi under reduced fertigation was most effectively maintains the fruit integrity.

Key words: Bitter gourd, Fertigation levels, Postharvest shelf life, Storage conditions, Physiological loss in weight

Bitter gourd (*Momordica charantia* L.), a member of the Cucurbitaceae family, is extensively grown in tropical and subtropical areas of Asia, Africa and the Caribbean. It is highly regarded as a nutritious vegetable along with its therapeutic properties [1]. Apart from its wider acceptance for the bitter taste, it also contains large number of phytoactive compounds with medicinal importance [2]. Bitter gourd has been identified as a rich source of phenolic constituents, recognized for their powerful antioxidant potential [3]. The green fruits exhibited the greatest antioxidant potential [4].

Momordica charantia is nutritionally richer than many other cucurbit species, owing to its higher concentrations of essential minerals like iron and vitamins such as ascorbic acid [5]. Singla *et al.* [6] highlighted the nutritional significance of bitter gourd, emphasizing its richness in key macro-minerals (K, Ca, Mg) and micro-minerals (Fe, Zn, Cu, Mn) and recommended whole fruit consumption to optimize mineral intake and support overall health. It is also a rich source of vitamin A, vitamin E, thiamine, riboflavin, niacin, folate and vitamin C, along with essential minerals such as potassium, iron, calcium, magnesium, phosphorus and zinc. It also contains a good amount of dietary fiber and is composed of health promoting compounds, including primary metabolites like sugars, proteins and chlorophyll, and secondary metabolites such as phenolics, carotenoids, triterpenoids, alkaloids and saponins, enhancing both its nutritional and therapeutic value [2]. Secondary metabolites in bitter gourd have minimal nutritional value but play an important role in providing health benefits and supporting overall well-being [7].

Efficient fertigation also enhances the shelf life of bitter gourd fruits [8]. Bitter gourd fruits are highly perishable and prone to rapid yellowing and decay when stored under tropical ambient conditions [9]. Fruits and vegetables undergo rapid quality deterioration after harvest, primarily due to ongoing metabolic activity and elevated respiration and microbial proliferation at higher temperatures [10-11]. However, storing them at lower temperature has shown an extended shelf life [12].

Fertigation plays a significant role in influencing fruit quality and post-harvest shelf life. Since bitter gourd is highly perishable and prone to rapid deterioration, it is important to adopt better storage strategies that can enhance its shelf life. In this context, the present study was conducted to evaluate the postharvest shelf life of bitter gourd hybrids under different storage conditions, to identify the most suitable fertigation and storage combinations for maintaining quality and extended shelf life.

MATERIALS AND METHODS

A field experiment was conducted at the Department of Vegetable Science, College of Agriculture, Vellanikkara, to evaluate the postharvest shelf life of bitter gourd (*Momordica charantia* L.) under different fertigation levels and storage conditions. The study involved four bitter gourd hybrids, Prajani (V1), Pragathi (V2), Maya (V3) and Pusa Hybrid 4 (V4) which were subjected to six fertigation treatments, 75% of the recommended dose of fertilizers, RDF (T1), 100% RDF (T2),

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125% RDF (T3), 150% RDF (T4), Package of Practice recommendation KAU (T5) and absolute control (T6).

For the assessment of postharvest shelf life, fruits from each treatment combination were stored under two storage conditions, ambient room temperature (S1) and refrigerated storage in polythene bag (S2). The experiment followed a completely randomized design (CRD) with three factors in two replications, considering the effects of storage conditions, fertigation levels and hybrids.

Physiological loss in weight

To assess shelf life and postharvest quality of the fruit samples, physiological loss in weight (PLW) was recorded at regular intervals during storage under room temperature and refrigerated conditions. PLW was calculated by comparing the initial weight of the fruit with its corresponding weight at each observation point [13]. The percentage loss in weight was determined using the formula:

$$\text{PLW (\%)} = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100$$

Visual scoring for fruit quality and appearance

Scoring was done at every three days interval based on the score chart developed by Zong *et al.* [14].

- 9- Excellent visual quality, colour, flesh, firm
- 7- Good visual quality, colour, turning soft
- 5- Fair (suitable) visual quality, yellowing, soft
- 3- Poor (edible) visual quality, yellowing, soft
- 1- Inedible, poor visual quality, shrivelled, decayed

RESULTS AND DISCUSSION

Physiological loss in weight

Physiological loss in weight (PLW) was significantly influenced by storage condition, fertigation levels and hybrids across three observation periods (Day 3, Day 6, and Day 9). The analysis of variance indicated that all main factors and their interactions were highly significant at every stage of storage. Storage condition remained the dominant factor affecting PLW. Fruits stored under room conditions exhibited progressively increasing PLW (28.58% on Day 3, 38.00% on Day 6, and 68.55% on Day 9) compared to those stored under refrigerated conditions (2.07%, 3.34%, and 4.36%, on day 3, 6 and 9 respectively). These findings are consistent with earlier studies by Mohammed *et al.* [12], who reported that bitter gourd fruits stored at 5–7 °C with LDPE wrap maintained better fruit quality and experienced less deterioration, and by Valida *et al.* [15], who observed that storage at 7–10 °C significantly extended shelf life compared to higher temperature storage (21–25°C). Wijewardane *et al.* [16] reported lower PLW an additional 10 days of shelf life for bitter gourd stored at low temperature conditions.

Among fertigation treatments, T3 (38.631 %) and T2 (36.843 %) frequently exhibited higher mean PLW by Day 9, whereas T5 (33.791%) exhibited the lowest loss in weight. Higher doses of nitrogen reduced fruit quality hence frequent split application enhanced the post-harvest shelf life in bitter gourd fruits [8]. Optimal fertigation levels enhanced the keeping quality of pointed gourd fruits, with the highest shelf life and fruit quality recorded at 100% RDF, which was statistically comparable to 80% RDF [17]. Hybrid effects were consistent across storage durations, with V4 consistently showing the highest PLW and V1 exhibiting the lowest, indicating inherent differences in storability among hybrids. As

the storage period progressed, the mean PLW increased significantly, rising from 18.113% in V4 and 12.417% in V1 on day 3 to 40.337% in V4 and 33.676% in V1 by day 9.

The interaction effects further highlighted the combined influence of storage condition, fertigation level and hybrid selection on PLW. On Day 3, the combination S1T1V4 recorded the highest PLW (40.25%) while S2T1V2 recorded the lowest (0.16%). On Day 6, S1T5V3 exhibited the highest PLW (50.97%) compared to S2T4V4 with the lowest (0.53%). By Day 9, maximum PLW was observed for S1T3V4 (83.85%), whereas S2T1V2 recorded minimal PLW (1.08%) followed by S2T4V4 (1.458%) (Fig 1). These consistent trends demonstrate the cumulative impact of storage duration and treatment combinations on PLW. The results underscore the importance of integrated postharvest management the adoption of cold storage, judicious use of fertigation levels and the selection of suitable hybrids that can substantially mitigate physiological weight loss and prolong shelf life (Table 1).

Visual scoring

All freshly harvested bitter gourd fruits initially recorded a uniform visual score of 9 across the treatment combinations, showing excellent appearance, firmness, vibrant colouration and optimal texture. Over time, a decline in quality was observed. Fruits stored under refrigeration maintained higher visual scores with only slight deterioration, while those kept at room temperature exhibited a rapid decrease in quality, becoming nearly unmarketable (score 1) by Day 6. The fruits stored under refrigerated storage also recorded a reducing trend and attained a visual score value of less than five in day nine. Wijewardane *et al.* [16], reported a reduced spoilage and slower quality deterioration under low temperature storage.

Among the fertigation treatments, T4 (150% RDF) consistently maintained the highest average visual scores throughout the storage period, indicating better quality and extended shelf life compared to other treatments. In contrast, T6 recorded a rapid decline in quality from the initial to the final observation period. Regarding hybrid performance, Maya consistently retained better quality under refrigerated conditions, showing a mean score of 4.0 by 9th day. Significant interactions between mean fertigation treatments and hybrid combinations were observed. Under room temperature conditions, the combination T3V2 became unmarketable and inedible within three days of storage. Morales *et al.* [18] similarly reported that bitter gourd fruits stored under ambient conditions deteriorated in visual quality within four days or less. In contrast, under refrigerated conditions, the treatment combinations such as T4V3, T4V2, T1V4, and T2V4 maintained excellent visual quality (score 9) up to day six.

By day 9, all fruits stored at room temperature became unmarketable. Specific combinations under ambient storage, such as T6 with hybrids V2, V3 and V4, T2 with V1 and V2 and T3 with V2 showed the earliest visual decline, with significant deterioration noted by Day 6. Overall, refrigerated samples gave better physical appearance and quality, remaining marketable for approximately one weeks under most treatment combinations. Fruits stored at room temperature remained marketable for only about four days, with visible decay by Day 6. Bitter gourd can maintain acceptable visual quality for 10–14 days when stored at 10–12.5°C, while improper harvest maturity and higher temperatures lead to undesirable changes in colour, firmness and overall appearance [9].

Under refrigerated storage conditions, bitter gourd (*Momordica charantia* L.) fruits exhibited characteristic symptoms indicative of chilling injury after six days. Some fruits developed slight yellowing, particularly in the central

regions, accompanied by partial discoloration at the apical and basal ends, suggesting chlorophyll degradation and impaired ripening processes. In contrast, other fruits retained a dark green coloration but showed a slimy surface texture, water-soaked areas, and distinct surface pitting. Common symptoms observed across various treatments included mild shriveling, pitting,

water soaking, and varying degrees of discoloration, all confirming the occurrence of chilling injury under low-temperature storage. Visual manifestations such as pitted lesions, russetting, dark brown to black surface discoloration, and a high incidence of decay were consistent with chilling injury symptoms reported in bitter melon [14].

Table 1 Effect of fertigation on post-harvest shelf life of bitter melon

Physiological loss in weight (%)				Visual scoring				
Treatment	Day 3	Day 6	Day 9	Treatment	Day 0	Day 3	Day 6	Day 9
Factor A				Factor A				
S1	28.57 ^a	38.00 ^a	68.55 ^a	S1	-	5.16 ^b	3.58 ^b	1.00 ^b
S2	2.07 ^b	3.34 ^b	4.36 ^b	S2	-	8.08 ^a	6.50 ^a	4.87 ^a
Factor B				Factor B				
T1	16.31 ^a	20.54 ^c	36.61 ^b	T1	-	6.87 ^b	6.12 ^b	3.87 ^b
T2	16.19 ^a	21.04 ^b	36.84 ^b	T2	-	6.25 ^c	5.00 ^d	4.00 ^b
T3	13.95 ^c	19.90 ^d	38.63 ^a	T3	-	6.12 ^c	5.62 ^c	3.75 ^b
T4	13.86 ^c	19.49 ^d	36.39 ^b	T4	-	7.50 ^a	6.62 ^a	4.50 ^a
T5	15.13 ^b	21.47 ^{ab}	33.79 ^c	T5	-	6.00 ^c	5.37 ^c	3.75 ^b
T6	16.47 ^a	21.58 ^a	36.47 ^b	T6	-	7.00 ^b	4.50 ^e	3.75 ^b
Factor C				Factor C				
V1	12.41 ^d	16.90 ^d	33.67 ^c	V1	-	6.75 ^b	6.33 ^a	3.91 ^{ab}
V2	14.11 ^c	18.87 ^c	35.86 ^b	V2	-	6.41 ^c	5.16 ^c	3.66 ^b
V3	16.65 ^b	22.85 ^b	35.95 ^b	V3	-	7.08 ^a	5.66 ^b	4.08 ^a
V4	18.11 ^a	24.07 ^a	40.33 ^a	V4	-	6.25 ^c	5.00 ^c	4.08 ^a
A × B × C				A × B × C				
S1T1V1	24.18 ^{jk}	33.20 ⁱ	67.19 ^{ij}	S1T1V1	9.00	7.00 ^c	7.00 ^c	1.00 ⁱ
S1T1V2	28.95 ^h	35.06 ^h	74.89 ^d	S1T1V2	9.00	4.00 ^f	3.00 ^g	1.00 ⁱ
S1T1V3	26.54 ⁱ	34.67 ^h	61.16 ^m	S1T1V3	9.00	5.00 ^e	4.00 ^f	1.00 ⁱ
S1T1V4	40.25 ^a	49.00 ^b	75.47 ^{cd}	S1T1V4	9.00	3.00 ^g	2.00 ^h	1.00 ⁱ
S1T2V1	24.03 ^{jk}	31.03 ^j	63.03 ^l	S1T2V1	9.00	2.00 ^h	1.00 ⁱ	1.00 ⁱ
S1T2V2	32.30 ^e	40.73 ^f	64.50 ^{kl}	S1T2V2	9.00	3.00 ^g	1.00 ⁱ	1.00 ⁱ
S1T2V3	30.74 ^{fg}	40.29 ^f	78.86 ^b	S1T2V3	9.00	6.00 ^d	4.00 ^f	1.00 ⁱ
S1T2V4	31.68 ^{ef}	43.04 ^e	68.00 ^{hi}	S1T2V4	9.00	4.00 ^f	3.00 ^g	1.00 ⁱ
S1T3V1	20.76 ⁿ	28.04 ^k	66.54 ^{ij}	S1T3V1	9.00	7.00 ^c	7.00 ^c	1.00 ⁱ
S1T3V2	23.28 ^{kl}	30.00 ^j	70.00 ^{fg}	S1T3V2	9.00	1.00 ⁱ	1.00 ⁱ	1.00 ⁱ
S1T3V3	26.50 ⁱ	36.48 ^g	66.13 ^j	S1T3V3	9.00	7.00 ^c	6.00 ^d	1.00 ⁱ
S1T3V4	35.35 ^{cd}	43.42 ^e	83.85 ^a	S1T3V4	9.00	5.00 ^e	3.00 ^g	1.00 ⁱ
S1T4V1	22.08 ^{lmn}	31.29 ^j	71.34 ^f	S1T4V1	9.00	7.00 ^c	6.00 ^d	1.00 ⁱ
S1T4V2	22.03 ^{lmn}	31.23 ^j	64.23 ^l	S1T4V2	9.00	7.00 ^c	5.00 ^e	1.00 ⁱ
S1T4V3	30.13 ^{gh}	42.32 ^e	65.94 ^{jk}	S1T4V3	9.00	6.00 ^d	5.00 ^e	1.00 ⁱ
S1T4V4	28.84 ^h	40.85 ^f	76.96 ^c	S1T4V4	9.00	6.00 ^d	3.00 ^g	1.00 ⁱ
S1T5V1	21.72 ^{mn}	31.10 ^j	51.43 ^o	S1T5V1	9.00	4.00 ^f	4.00 ^f	1.00 ⁱ
S1T5V2	23.97 ^{jk}	32.99 ⁱ	58.40 ⁿ	S1T5V2	9.00	7.00 ^c	6.00 ^d	1.00 ⁱ
S1T5V3	34.62 ^d	50.97 ^a	74.05 ^{de}	S1T5V3	9.00	5.00 ^e	4.00 ^f	1.00 ⁱ
S1T5V4	36.70 ^{bc}	48.11 ^{bc}	73.08 ^e	S1T5V4	9.00	4.00 ^f	3.00 ^g	1.00 ⁱ
S1T6V1	22.95 ^{klm}	30.02 ^j	58.68 ⁿ	S1T6V1	9.00	7.00 ^c	5.00 ^e	1.00 ⁱ
S1T6V2	25.26 ^{ij}	35.27 ^{gh}	69.05 ^p	S1T6V2	9.00	6.00 ^d	1.00 ⁱ	1.00 ⁱ
S1T6V3	37.53 ^b	47.53 ^c	59.58 ⁿ	S1T6V3	9.00	6.00 ^d	1.00 ⁱ	1.00 ⁱ
S1T6V4	35.40 ^{cd}	45.40 ^d	82.80 ^a	S1T6V4	9.00	5.00 ^e	1.00 ⁱ	1.00 ⁱ
S2T1V1	2.83 ^{qrs}	2.98 ^{pqr}	4.33 ^{tuv}	S2T1V1	9.00	9.00 ^a	9.00 ^a	5.00 ^c
S2T1V2	0.16 ^v	0.79 st	1.08 ^y	S2T1V2	9.00	9.00 ^a	8.00 ^b	5.00 ^c
S2T1V3	2.97 ^{qr}	3.59 ^{op}	3.62 ^{uvw}	S2T1V3	9.00	9.00 ^a	7.00 ^c	6.00 ^d
S2T1V4	4.61 ^{op}	5.06 ^{mn}	5.17 st	S2T1V4	9.00	9.00 ^a	9.00 ^a	6.00 ^a
S2T2V1	1.87 ^{rstu}	2.72 ^{pqr}	7.35 ^{qr}	S2T2V1	9.00	8.00 ^b	7.00 ^c	5.00 ^c
S2T2V2	5.87 ^o	6.29 ^{lm}	8.10 ^q	S2T2V2	9.00	9.00 ^a	7.00 ^c	6.00 ^d
S2T2V3	1.95 ^{rstu}	2.26 ^{pqr}	2.63 ^{wxy}	S2T2V3	9.00	9.00 ^a	8.00 ^b	5.00 ^b
S2T2V4	1.10 ^{tuv}	2.01 ^{qrs}	2.26 ^{wxy}	S2T2V4	9.00	9.00 ^a	9.00 ^a	4.00 ^a
S2T3V1	2.26 ^{rst}	2.87 ^{pqr}	3.13 ^{vw}	S2T3V1	9.00	9.00 ^a	9.00 ^a	7.00 ^b
S2T3V2	1.34 ^{tuv}	4.84 ^{no}	4.87 ^{stu}	S2T3V2	9.00	7.00 ^c	7.00 ^c	6.00 ^d
S2T3V3	0.81 ^{tuv}	5.94 ^{mn}	6.36 ^{rs}	S2T3V3	9.00	8.00 ^b	8.00 ^b	4.00 ^b
S2T3V4	1.35 ^{stuv}	7.59 ^l	8.14 ^q	S2T3V4	9.00	5.00 ^e	4.00 ^f	4.00 ^f
S2T4V1	0.64 ^{uv}	1.56 ^{rst}	2.10 ^{wxy}	S2T4V1	9.00	7.00 ^c	7.00 ^c	7.00 ^c
S2T4V2	1.31 ^{tuv}	1.85 ^{qrst}	2.81 ^{vwxy}	S2T4V2	9.00	9.00 ^a	9.00 ^a	7.00 ^a
S2T4V3	5.52 ^{op}	6.30 ^{lm}	6.33 ^{rs}	S2T4V3	9.00	9.00 ^a	9.00 ^a	6.00 ^a
S2T4V4	0.34 ^v	0.53 ^t	1.45 ^{xy}	S2T4V4	9.00	9.00 ^a	9.00 ^a	6.00 ^c

S2T5V1	1.06 ^{tuv}	3.09 ^{pq}	3.50 ^{uvw}	S2T5V1	9.00	7.00 ^c	7.00 ^c	7.00 ^c
S2T5V2	0.78 ^{tuv}	1.47 ^{rst}	2.34 ^{wxy}	S2T5V2	9.00	8.00 ^b	7.00 ^c	6.00 ^c
S2T5V3	1.19 ^{tuv}	1.72 ^{qrst}	3.25 ^{vw}	S2T5V3	9.00	6.00 ^d	5.00 ^c	4.00 ^c
S2T5V4	1.05 ^{tuv}	2.35 ^{pqr}	4.24 ^{tuv}	S2T5V4	9.00	7.00 ^c	7.00 ^c	4.00 ^c
S2T6V1	4.59 ^{klm}	4.85 ^{no}	5.44 st	S2T6V1	9.00	7.00 ^c	7.00 ^c	4.00 ^c
S2T6V2	4.06 ^{pq}	5.93 ^{mn}	10.04 ^p	S2T6V2	9.00	7.00 ^c	7.00 ^c	5.00 ^c
S2T6V3	1.33 ^{tuv}	2.10 ^{qrs}	3.56 ^{uvw}	S2T6V3	9.00	9.00 ^a	7.00 ^c	3.00 ^c
S2T6V4	0.65 ^{uv}	1.55 ^{rst}	2.59 ^{wxy}	S2T6V4	9.00	9.00 ^a	7.00 ^c	2.00 ^c
CV (%)	4.82	3.40	2.11	CV (%)	-	6.90	7.36	7.59
CD (5%)	1.48	1.41	1.54	CD (5%)	-	0.92	0.82	0.91

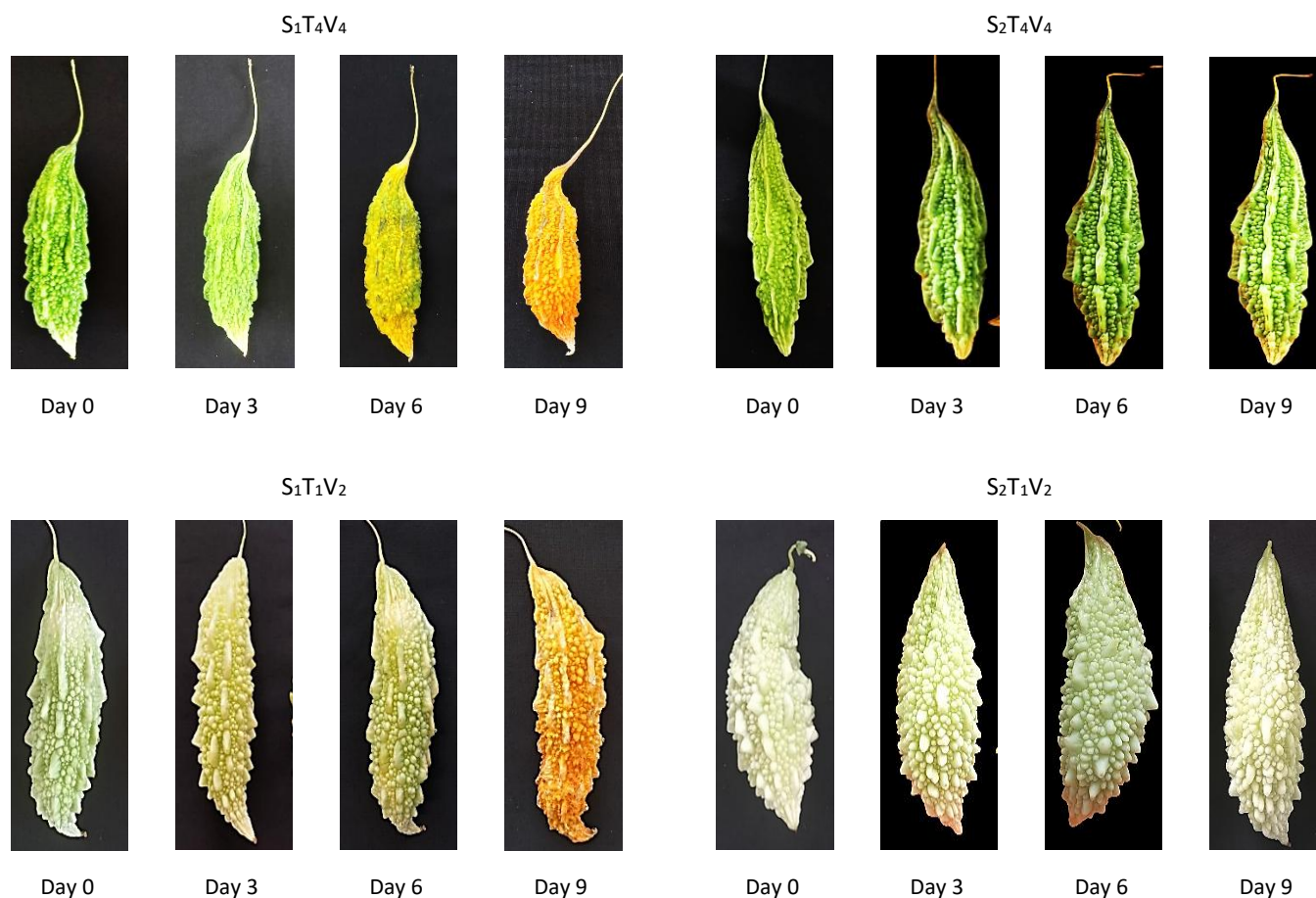


Fig 1 Bitter gourd hybrids under different levels of fertigation and storage conditions

CONCLUSION

Refrigerated conditions significantly reduce the physiological loss in weight (PLW) of bitter gourd compared to ambient storage, as lower temperatures slow down respiration and transpiration. PLW is primarily caused by water loss through transpiration and respiration, and refrigeration minimizes these processes. Bitter gourd fruits stored under refrigerated condition in polyethylene bags with reduced fertigation (75 % RDF) exhibited the least physiological weight

loss and maintained superior visual quality. In contrast, ambient storage led to rapid weight and visual deterioration, rendering most combinations unmarketable by day six. The hybrid Prajani gave lowest PLW. While refrigeration is beneficial for reducing weight loss, it can negatively impact texture of fruits if the bitter gourd is stored for long periods.

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