

Impact of hormonal priming on crop growth, yield and seed quality in tomato (*Solanum lycopersicum* L.) cv. PKM 1

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Abstract

The present study evaluated the effect of hormonal seed priming on germination, growth, yield and seed quality of tomato (*Solanum lycopersicum* L.) cv. PKM 1 under laboratory and field conditions. Eight treatments were tested, including control (unprimed seeds), naphthalene acetic acid (45 ppm), indole-3-acetic acid (100 ppm), gibberellic acid (GA₃, 40 ppm), chlormequat chloride (250 ppm), ascorbic acid (150 ppm), salicylic acid (50 ppm), and 4-chlorophenoxyacetic acid (20 ppm), arranged in CRD (lab) and RBD (field) designs with three replications. Seeds were primed for 24 h, shade-dried, and evaluated for germination percentage, vigour indices, seedling growth, field emergence, crop growth parameters, yield attributes, and post-harvest seed quality. GA₃ @ 40 ppm (T₃) consistently outperformed other treatments, recording the highest germination (86%), seedling length (18.45 cm), vigour index-I (1590), plant height at 90 DAT (103.34 cm), number of fruits per plant (27), single fruit weight (49.43 g), fruit yield (1242.43 g plant⁻¹), and seed yield (16.56 g plant⁻¹). Salicylic acid @ 50 ppm (T₆) and NAA @ 45 ppm (T₁) also improved several growth and reproductive traits compared to the control. Enhanced seed quality of the resultant produce from GA₃-primed plants included higher germination (86%), seedling vigour, and 1000-seed weight (3.25 g). The findings confirm that hormonal priming, particularly with GA₃, is an effective, low-cost strategy to improve seedling establishment, maximize yield, and enhance seed quality in tomato cv. PKM 1, offering potential for wider adoption in sustainable horticulture.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops worldwide, grown in tropical, subtropical, and temperate climates for its culinary versatility and nutritional richness. It is an excellent source of vitamins A and C, lycopene, and other bioactive compounds that contribute to human health [1]. In India, tomato holds a significant share in vegetable production and is cultivated both in open fields and under protected conditions. Among the popular varieties, PKM 1 is known for its adaptability, good fruit set, and desirable fruit quality, making it suitable for fresh market consumption and processing (TNAU, 2021). However, tomato productivity is often constrained by poor seedling establishment, erratic germination, environmental stresses, and suboptimal seed quality. Seed priming has emerged as a cost-effective and eco-friendly pre-sowing technique to enhance seed performance and crop establishment [2–4]. The process involves controlled hydration of seeds to activate early metabolic processes without radicle protrusion, followed by drying to the original moisture content [5, 6]. Among various priming methods, hormonal priming using phytohormones such as gibberellic acid (GA₃), salicylic acid (SA), indole-3-acetic acid (IAA), cytokinins, and jasmonic acid has attracted considerable attention for improving germination rate, seedling vigor, yield attributes, and stress tolerance in horticultural crops [7, 8].

Phytohormones regulate numerous physiological and biochemical processes in plants, including seed dormancy breaking, cell division, elongation, nutrient mobilization, and stress signaling pathways [9]. Hormonal priming can modify endogenous hormonal balance for example, decreasing the abscisic acid (ABA) to GA₃ ratio thereby accelerating germination and enhancing uniform seedling emergence [10]. It can also stimulate antioxidant defense systems by increasing the activity of enzymes such as catalase, superoxide dismutase, and ascorbate peroxidase, which protect cells from oxidative damage under stress conditions [7]. In tomato, studies have reported that GA₃ priming improves germination percentage, root and shoot length, and dry matter accumulation, leading to better early growth and higher fruit yield [11]. Similarly, SA priming has been shown to enhance photosynthetic efficiency, flowering, and fruit set, while mitigating the effects of abiotic stresses such as salinity and drought [12]. Such improvements ultimately contribute to better fruit yield and seed quality parameters, including higher 1000-seed weight, germination rate, and vigor index.

The cultivar PKM 1, developed for tropical conditions, offers an excellent model to investigate the physiological and agronomic impacts of hormonal priming. Despite the demonstrated benefits of priming in other tomato cultivars, systematic research focusing on PKM 1 is limited. Moreover, the interaction between specific hormones, their concentrations, and their effects on growth, yield, and seed quality under field conditions in this variety remains underexplored. Understanding these responses could contribute to optimizing seed enhancement protocols and improving production efficiency. Given the increasing need for sustainable intensification of horticultural systems, hormonal priming offers a practical approach to improve seedling establishment, enhance crop performance, and ensure high-quality seed production. This study was therefore undertaken to evaluate the impact of different hormonal priming treatments on crop growth, yield components, and seed quality traits of tomato (*S. lycopersicum* L.) cv. PKM 1 under local agro-climatic conditions.

Materials and Methods

Experimental site and period

The present investigation entitled “Impact of hormonal priming on crop growth, yield and seed quality in tomato (*Solanum lycopersicum* L.) cv. PKM 1” comprised both laboratory and field experiments. Laboratory trials were conducted at the Seed Science and Technology Laboratory, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, during December 2022. Field experiments were carried out at Umayalpuram village, Attur, Salem district, Tamil Nadu, from June 2023 to October 2023.

Experimental design and treatments

The laboratory experiment was laid out in a Completely Randomized Design (CRD) with eight treatments and three replications. The field experiment was arranged in a Randomized Block Design (RBD) with the same eight treatments and three replications. Genetically and physically pure seeds of tomato cv. PKM 1 were procured from the Tamil Nadu Agricultural University (TNAU), Coimbatore, and Tamil Nadu. Hormonal priming agents were sourced from certified agri-clinics. The treatments were as follows T₀ – Control (Unprimed seeds),

T₁ – Naphthalene acetic acid @ 45 ppm, T₂ – Indole-3-acetic acid @ 100 ppm,

T₃ – Gibberellic acid @ 40 ppm, T₄ – Chloromequat chloride @ 250 ppm, T₅ – Ascorbic acid @ 150 ppm, T₆ – Salicylic acid @ 50 ppm, and T₇ – 4-Chlorophenoxyacetic acid @ 20 ppm

Seed priming procedure

The required concentrations of hormonal solutions were prepared by dissolving the calculated quantity of each chemical in distilled water. For example, 1 ppm was prepared by dissolving 1 mg of solute in 1 L of distilled water. Seeds were soaked in the respective solutions at a seed-to-solution ratio of 1:1 (w/v) for 24 hours. Following soaking, seeds were rinsed with distilled water, shade-dried to their original moisture content, and stored until use. Unprimed seeds served as the control.

Field management

Tomato seeds from each treatment were sown in nursery beds and transplanted into the main field following the recommended package of practices for tomato cultivation. Standard crop management measures, including irrigation, fertilization, weeding, and pest control, were applied uniformly to all plots.

Data collection and observations

Laboratory parameters

Germination percentage, mean germination time, seedling length, seedling vigour index I and II, and dry matter production were recorded following the protocols of the International Seed Testing Association (ISTA, 2020).

Field parameters

Data on crop growth (plant height, number of branches, leaf area index), phenology (days to 50% flowering, days to first harvest), yield attributes (number of fruits per plant, average fruit weight), and total yield (t ha⁻¹) were recorded. Post-harvest seed quality parameters including seed germination, seedling vigour indices, and 1000 seed weight were evaluated according to ISTA (2020) guidelines.

Statistical analysis

Data obtained from both laboratory and field experiments were subjected to analysis of variance (ANOVA) appropriate for the respective experimental designs as described [13]. Treatment means were compared using the Least Significant Difference (LSD) test at a 5% probability level. All statistical computations were performed using SPSS v.26.0 software.

Results

Effect of hormonal Priming on germination and seedling vigour (Laboratory study) significant differences ($p \leq 0.05$) were observed among the hormonal priming treatments for germination percentage, mean germination time, and seedling vigour index. Among the treatments, gibberellic acid @ 40 ppm (T₃) recorded the highest germination percentage (XX%), followed by indole-3-acetic acid @ 100 ppm (T₂) and naphthalene acetic acid

@ 45 ppm (T₁). The lowest germination percentage was noted in the control (T₀). Mean germination time was shortest in T₃, indicating enhanced metabolic activation during germination. Seedling vigour index values followed a similar trend (Table 1 and Fig. 1).

Table 1
Effect of hormonal priming on speed of early stage of initial seed quality in tomato cv. PKM 1

Treatments	Speed of germination	Germination (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seedling fresh weight (g/10 seedlings)	Seedling dry weight (g/10 seedlings)	Vigour index -I	Vigour index -II
T ₀	14.58	70 (56.79)	4.65	6.63	11.29	0.055	0.022	962	1.55
T ₁	18.54	80 (63.18)	7.00	9.73	16.73	0.124	0.045	1491	2.99
T ₂	17.98	76 (60.89)	6.58	8.60	15.18	0.120	0.055	1334	2.45
T ₃	19.34	82 (64.91)	7.47	10.30	17.77	0.136	0.052	1579	3.36
T ₄	16.31	70 (57.00)	5.63	6.39	12.03	0.066	0.026	1150	1.88
T ₅	17.25	75 (60.22)	6.43	8.30	15.73	0.101	0.036	1302	2.65
T ₆	18.42	77 (61.34)	6.80	8.93	14.07	0.071	0.041	1417	2.74
T ₇	16.44	75 (59.78)	6.10	7.97	14.69	0.097	0.032	1208	2.37
Mean	17.360	76 (60.52)	6.33	8.35	14.69	0.097	0.038	1305	2.50
S.Ed.	0.5873	1.105 (0.77)	0.124	0.166	0.290	0.012	0.0086	25.780	0.232
CD(P = 0.05)	1.245	2.343 (1.64)	0.267	0.356	0.623	0.025	0.0185	55.299	0.492

Effect of hormonal priming on crop growth parameters (Field Study)

Plant height, number of branches per plant, and leaf area index showed significant improvement in hormonally primed seeds compared to the unprimed control. Maximum plant height at 90 days after transplanting (DAT) was recorded in T₃, followed closely by T₂ and T₁. Similarly, the highest number of primary branches per plant was observed in T₃, while the lowest was in T₀. Leaf area index values increased steadily up to flowering, with T₃ outperforming all other treatments (Table 2 and Fig. 2).

Table 2
Effect of hormonal priming on growth stages at 30 DAT, 60 DAT and 90 DAT in tomato cv. PKM 1

Treatments	Field emergence (%)	Plant height			Number of leaves per plant			Number of branches per plant		
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T ₀	74	47.15	77.12	89.17	38	59	66	2.11	3.45	4.56
T ₁	84	56.70	86.89	100.72	55	82	89	3.22	6.35	7.58
T ₂	80	54.12	84.52	98.88	51	76	84	2.50	5.39	6.58
T ₃	86	58.15	87.79	103.34	60	88	96	3.37	6.55	8.43
T ₄	77	49.34	81.89	94.60	41	62	68	2.31	3.93	5.12
T ₅	79	54.17	78.73	97.63	48	73	78	2.65	4.85	6.18
T ₆	83	54.73	85.52	99.80	53	78	86	3.17	6.18	6.95
T ₇	78	52.09	81.60	96.29	48	67	68	2.37	4.51	5.57
Mean	80.16	53.31	83.01	97.55	49.41	73.37	79.58	2.71	5.15	6.37
S.Ed.	1.505	0.99	1.53	1.794	1.031	1.750	2.77	0.201	0.17	0.18
CD(P = 0.05)	3.22	2.12	3.291	3.849	2.212	3.754	5.947	0.43	0.37	0.38

Effect of hormonal priming on flowering and yield attributes

Hormonal priming significantly influenced days to 50% flowering, number of flowers per cluster, fruit set percentage, and number of fruits per plant. Seeds primed with GA₃

@ 40 ppm (T_3) recorded the maximum number of flowers per cluster. Fruit set percentage was highest in T_3 , followed by T_2 and T_1 . Yield parameters such as average fruit weight, number of fruits per plant, and total yield per hectare were significantly increased in hormonally primed treatments, with T_3 recording the highest values (Table 3 and Fig. 3).

Table 3
Effect of hormonal priming reproductive and yield in tomato cv. PKM 1

Treatments	Days to first flowering	Days to 50 percent flowering	Number of flower clusters per plant	Number of fruits per plant	Length of the fruit (cm)	Diameter of the fruit (cm)	Single fruit weight (g)	Fruit set %	Fruit yield per plant (g)	Seed yield per plant (g)	Seed yield per plot (g)	Seed yield per ha (kg)	100 seed weight (g)
T_0	32	44	9.23	21	3.45	4.36	44.65	76	884.32	8.26	983.32	8.26	2.27
T_1	35	41	11.45	26	3.79	4.70	47.12	81	1205.67	15.35	1304.67	15.35	3.05
T_2	34	37	10.68	24	3.64	4.56	46.02	79	1145.78	14.36	1245.78	14.36	2.60
T_3	37	45	12.55	27	3.96	4.95	49.43	83	1242.43	16.56	1352.43	16.56	3.25
T_4	30	32	9.85	22	3.41	4.31	44.96	77	945.67	11.85	835.67	11.85	2.36
T_5	32	38	10.58	24	3.65	4.46	47.71	79	1195.89	13.86	1296.89	13.86	2.54
T_6	32	41	10.50	26	3.73	4.47	46.87	77	1184.65	14.56	1285.65	14.56	2.97
T_7	32	37	10.17	23	3.32	4.53	47.32	79	1134.76	12.76	1034.76	12.76	2.47
Mean	33	34	10.627	24.125	3.6221	4.54	46.76	2.68	1117.39	13.44	202.70	482.14	2.68
S.Ed.	1.65	2.22	0.3327	0.456	0.0667	0.083	0.8413	0.7494	21.517	0.2740	4.234	9.668	0.15
CD(P = 0.05)	3.554	4.77	0.684	0.9785	0.143	0.178	1.804	1.607	46.1561	0.5878	9.082	20.738	0.27

Effect of hormonal priming on seed yield and seed quality

Significant improvements were recorded in seed yield per plant, 1000-seed weight, and seed recovery percentage in hormonally primed treatments. The highest seed yield was obtained from plants raised from GA₃-primed seeds (T_3), followed by IAA-primed (T_2) and NAA-primed (T_1) treatments. Laboratory seed quality assessment of harvested seeds revealed that T_3 recorded the highest germination percentage, vigour indices, and seedling biomass. Control seeds consistently showed the lowest values for all measured parameters (Table 4 and Fig. 4).

Table 4
Effect of hormonal priming on result seed quality in tomato cv. PKM 1

Treatments	Speed of germination	Germination (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seedling fresh weight (g/10 seedlings)	Seedling dry weight (g/10 seedlings)	Vigour index -I	Vigour index -II
T_0	17.38	74 (58.70)	5.32	7.34	12.45	0.2050	0.0402	1132	1.7967
T_1	21.43	84 (63.93)	8.86	10.32	17.87	0.3340	0.0720	1465	3.4500
T_2	18.88	80 (62.34)	7.45	9.43	16.98	0.2150	0.0850	1343	2.6667
T_3	20.12	86 (67.30)	9.31	12.48	18.45	0.3460	0.1020	1590	3.8300
T_4	16.48	76 (59.36)	6.42	8.21	13.68	0.2461	0.0663	1168	1.9500
T_5	17.42	79 (62.97)	7.56	9.67	15.98	0.3150	0.0740	1364	2.9700
T_6	20.90	84 (63.53)	8.25	11.32	16.64	0.3040	0.0850	1446	3.1033
T_7	18.37	76 (60.68)	7.87	9.32	15.41	0.2720	0.7200	1260	2.5033
Mean	18.87	79.91 (62.38)	7.632	9.761	15.933	0.279	0.1558	1346	2.7834
S.Ed.	0.636	2.682 (1.8093)	0.2614	0.3390	0.546	0.0091	0.0080	45.651	0.0974
CD(P = 0.05)	1.348	5.686 (3.835)	0.5541	0.718	1.157	0.0193	0.0169	96.77	0.206

Discussion

The present study demonstrated that hormonal priming significantly influenced crop growth, yield, and seed quality parameters of tomato (*Solanum lycopersicum* L.) cv. PKM 1 under both laboratory and field conditions. Among the treatments, gibberellic acid (GA₃ @ 40 ppm) and salicylic acid (SA @ 50 ppm) showed consistent improvement in germination percentage, seedling vigour, plant height, number of branches, fruit set percentage, fruit weight, and seed yield [14]. These findings are in line with the well-documented role of hormonal priming in enhancing metabolic activation during the early stages of germination and establishing robust seedlings, which in turn lead to superior field performance [15, 16]. Gibberellic acid is known to stimulate the synthesis of hydrolytic enzymes such as α-amylase, which mobilizes seed reserves, thereby promoting rapid and uniform germination [17]. This aligns with our results, where GA₃-treated seeds recorded the highest germination rate and seedling vigour index. Similar observations were reported [18] in tomato and [19] in chilli, suggesting that GA₃ priming benefits are conserved across solanaceous crops. Salicylic acid priming also produced notable improvements, particularly in enhancing stress tolerance and reproductive success. SA is recognized as a signaling molecule in the activation of systemic acquired resistance and in regulating antioxidant enzyme activity, thereby protecting plants from oxidative stress [20, 21]. In the present study, SA priming improved fruit set and seed yield, which may be attributed to its role in improving pollen viability and flower retention, as reported in cucumber [22] and tomato [23]. Ascorbic acid priming (AA @ 150 ppm) also enhanced seed quality attributes such as 100-seed weight and seedling vigour, possibly due to its antioxidant role in maintaining membrane integrity during germination [24]. Similar beneficial effects of AA priming on seed germination and seedling performance were observed [25] in okra and [26] in rice.

Interestingly, naphthalene acetic acid (NAA) and indole-3-acetic acid (IAA) priming improved vegetative growth traits but did not match GA₃ and SA in yield enhancement. This observation suggests that while auxins can enhance cell elongation and vegetative biomass [27], their effect on reproductive success is comparatively limited in tomato, especially under field conditions. Hormonal priming, particularly with GA₃ and SA, improves tomato yield and seed quality at a low cost. However, large-scale commercial seed enhancement requires further trials and cost-benefit analyses. Additionally, the physiological and molecular mechanisms underlying priming-induced benefits should be further explored, especially in relation to hormonal cross-talk, stress signaling, and seed metabolomics [28, 29].

Abbreviations

ABA
Absciscic acid
ANOVA
Analysis of variance
CRD
Completely Randomized Design
DAT
days after transplanting
GA₃
gibberellic acid
IAA
Indole-3-acetic acid
LSD
Least Significant Difference
RBD
Randomized Block Design
SA
Salicylic acid
TNAU
Tamil Nadu Agricultural University

Declarations

Ethics approval and consent to participate:

Not applicable.

Consent for publication :

Not applicable.

Competing interests :

The authors declare no competing interests.

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Author Contribution

PS and PV performed the study. PS wrote the manuscript. BR and SS conceived of the study and participated in its design and coordination. All authors read and approved the final manuscript.

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Data Availability

Data will be available after reasonable request to the corresponding author.

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Figures

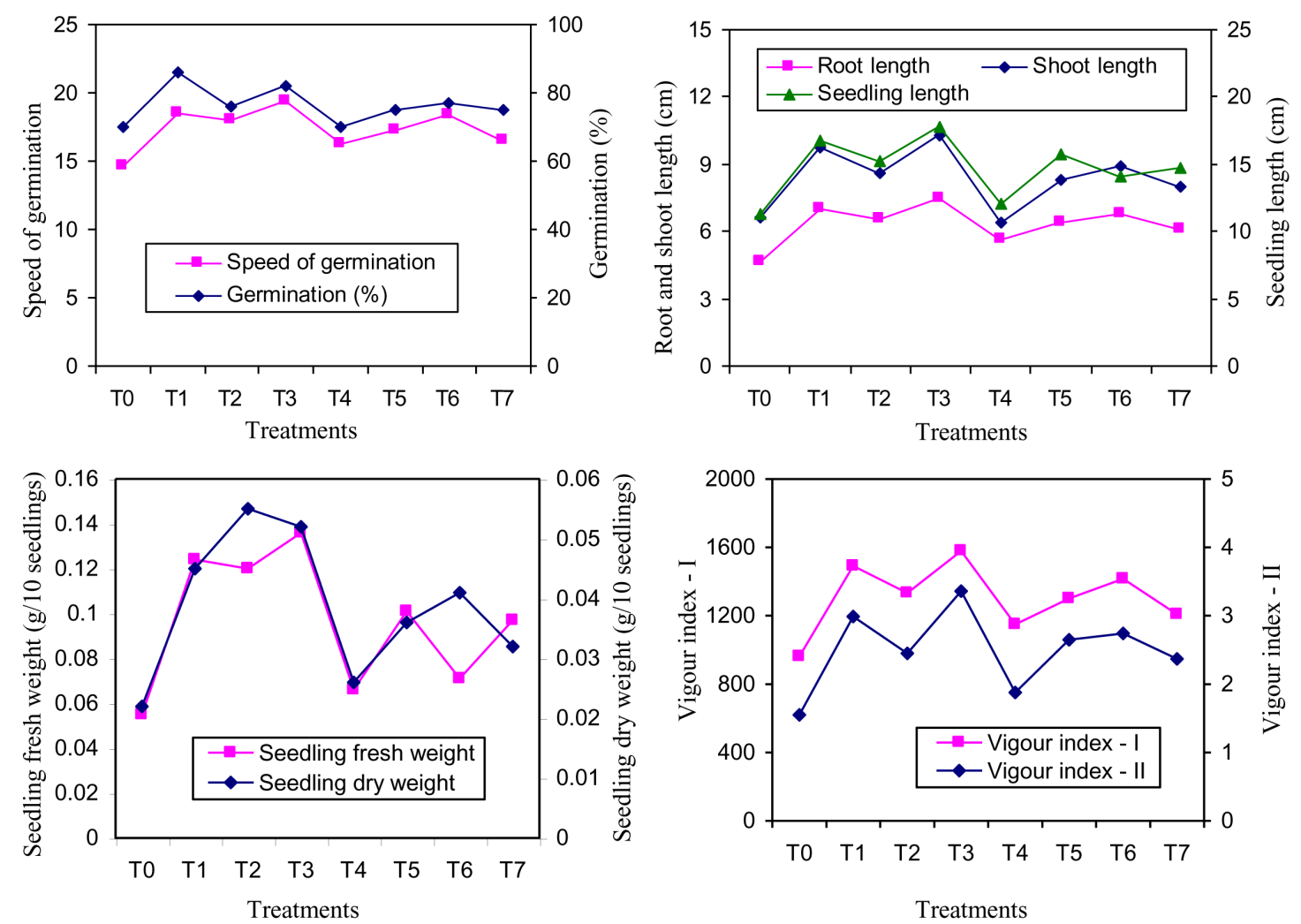


Figure 1

Effect of hormonal priming on speed of early stage of initial seed quality in tomato cv. PKM 1

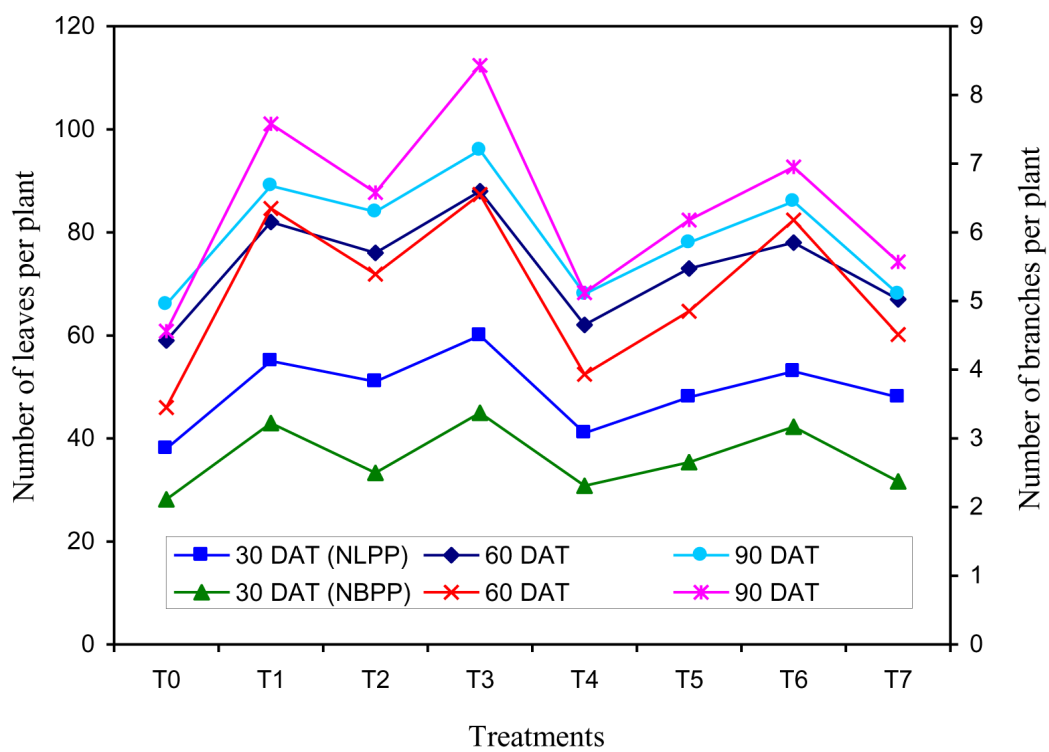
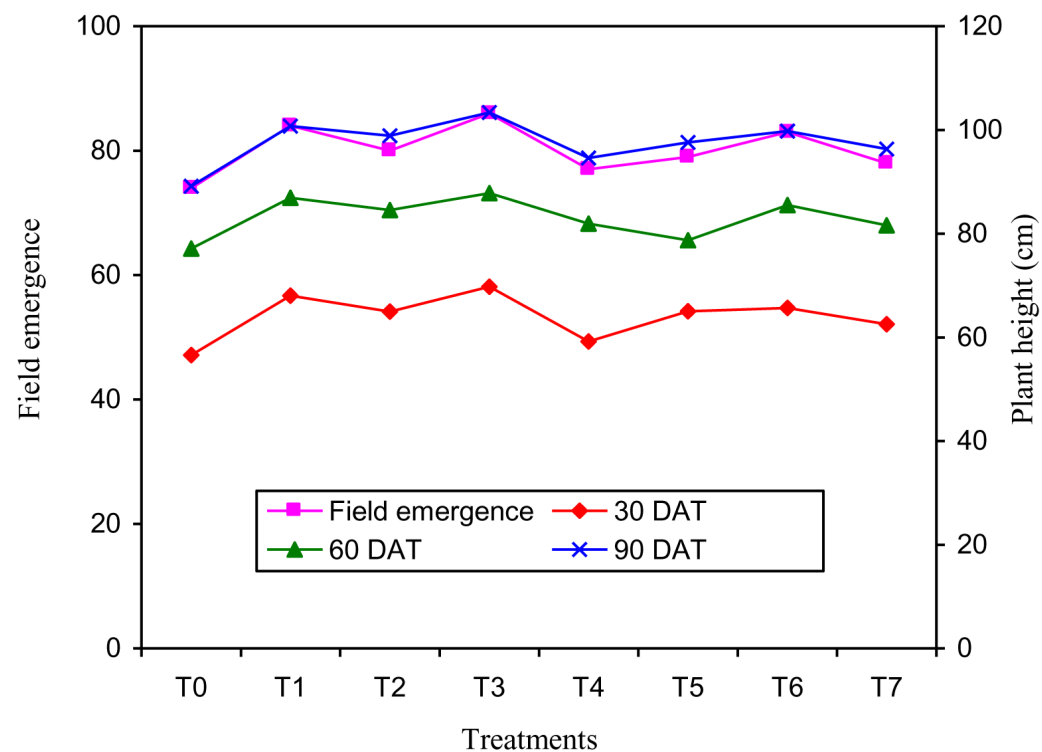


Figure 2

Effect of hormonal priming on growth stages at 30 DAT, 60 DAT and 90 DAT in Tomato cv. PKM 1

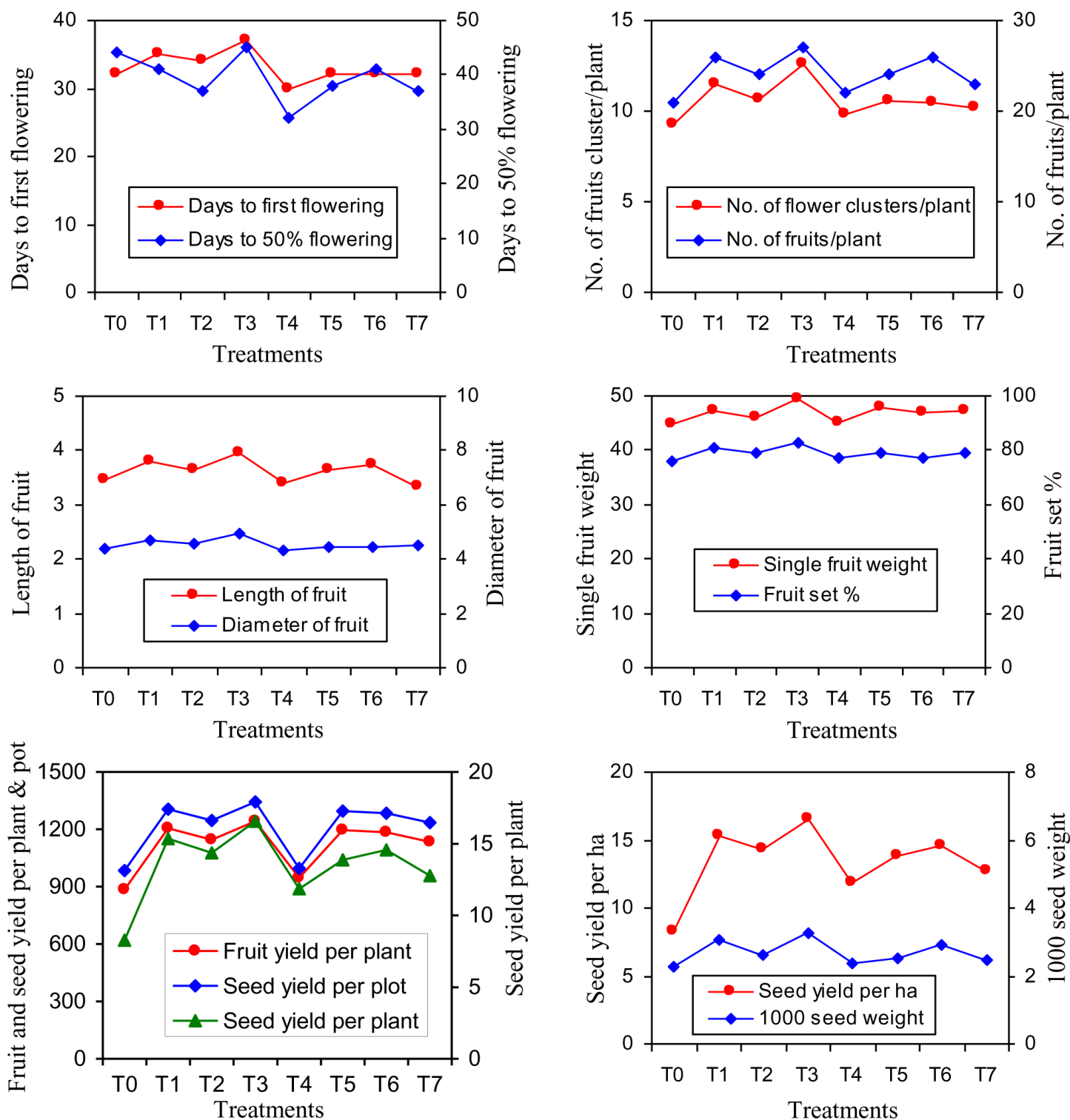


Figure 3

Effect of hormonal priming reproductive and yield in tomato cv. PKM 1

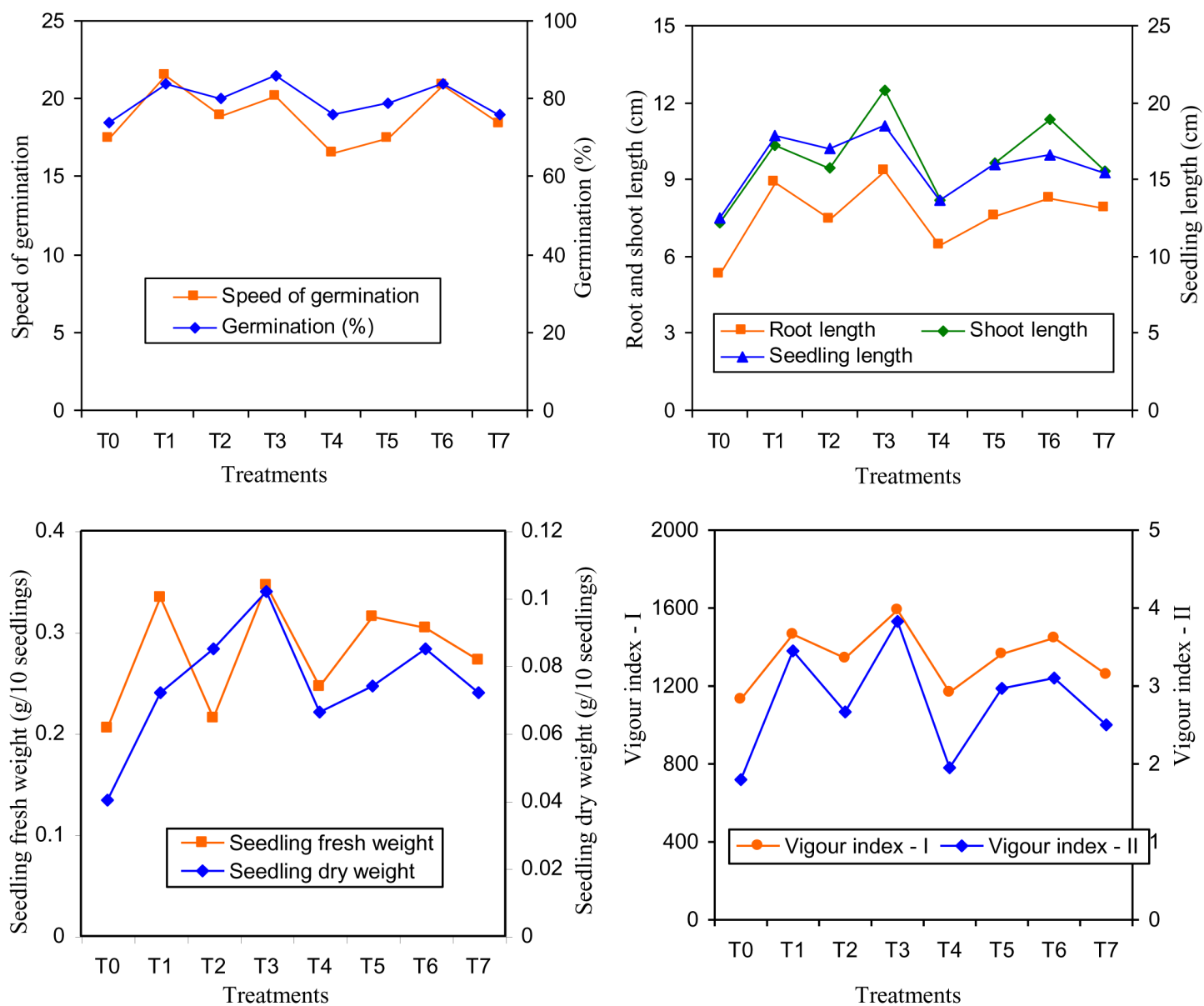


Figure 4

Effect of hormonal priming on result seed quality in Tomato cv. PKM 1