
Research Article

Effects of fermented banana pseudo-stem sap (*Musa acuminata* L.) on the growth and yield attributing characters of marigold variety Karma 555-Orange

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Abstract

The high cost of marigold production through the application of synthetic fertilizers and micronutrients is a major concern for Nepalese farmers. Every year, the nutrient-rich banana pseudo-stems are wasted after harvest. Utilizing the banana's pseudo-stem for increasing marigold productivity through sustainable agricultural practices, an experiment was conducted to determine the optimum concentration of banana pseudo-stem sap (BPS) to be applied by foliar spraying to marigold variety (Karma 555 – Orange). The BPS was mixed and enriched with different ingredients, such as cow urine, cow dung, neem leaf, green gram leaf, pulse flour, vermin-liquor, jaggery, and fermented curd. The mixture was incubated under anaerobic conditions before applying the foliar spray. The study was carried out in a completely randomized block design, with three replications and seven treatments. The treatments were 0.5 % BPS, 1 % BPS, 2 % BPS, 3 % BPS, 4 % BPS, 5 % BPS, and the control. Data were recorded at 50, 70, and 90 days after transplantation (DAT). Among the treatments, the 3 % BPS solution showed significant effects on most of the growth parameters: plant height (85.07 cm), plant spread (63.47 cm) at 5% level at 90 DAT, and yield attributes such as the number of flowers per plant (74.00) at 5% level, individual flower weight (8.10 g), individual flower diameter (7.55 cm), and flower yield (597.25 g plant⁻¹) at 1% level of significance respectively. It was found that growth and yield attributes increased with increasing concentrations of BPS up to 3 % and decreased thereafter. According to the results, foliar spray of marigold with 3 % BPS (enriched solution) resulted in the highest yield and yield components of marigold in the Chitwan area which could be an effective alternative to synthetic hormones for enhancing the growth and quality of marigolds under field conditions.

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1. Introduction

The popular beautiful flower, the African marigold (*Tagetes erecta* L.), is a member of the Asteraceae family and is used mostly for gardening, decorating, religious offerings, cosmetic preparations, and pharmaceuticals (Kk et al., 2018; Dahal et al., 2021). Marigold is a tall, annual plant with narrow, serrated compound leaves and a green stem that is two meters tall (Kumar et al., 2020). They are frequently used as free flowers or garlands on cultural and social occasions (Mehta et al., 2022). Marigolds have the potential to be lucrative commercial flowers in Nepal owing to their cultural and religious significance (Dhakal et al., 2021). The remarkable adaptability of marigold to varied soils, climatic conditions, and ease of cultivation has made it commercially grown as loose flowers in Nepal and India (Choudhary et al., 2016). The marigold is now becoming one of the best-adopted flowers in Nepal because of its tendency for free flowering, short blooming time, wide variety of colors, shapes, sizes, and high quality (Kumar et al., 2010). Marigolds produced in Nepal are mostly yellow to orange in color, which serves as the perfect combination for any color scheme (Dahal et al., 2021).

Marigold plays a significant role as a raw material in numerous industrial sectors because of its high carotenoid, essential oil, and alkaloid contents (Gutierrez et al., 2006). Production of marigolds is minimal during the peak season (July to December) due to a lack of technical knowledge among farmers, lack of high-yielding varieties, crop failure due to harsh climatic conditions, and market constraints. Flowers are imported in large quantities from Calcutta and Siliguri (West Bengal state of India), as Nepal cannot supply rising demand alone (Dhakal et al., 2021). Every year, more than 100 million flowers and garlands are imported into Nepal, especially during the festival and holiday seasons, because the annual productivity is quite low compared to the global yield (Adhikari et al., 2020). In recent times, marigolds have been cultivated on a large scale, yet their productivity is not optimal, and there is no proper cultivation technology to boost the yield potential. One of the major obstacles to its cultivation is the marigold's low yield and poor flower quality (Patokar et al., 2017). Farmers face challenges in providing exogenous nutrients, plant growth regulators, hormones, and fertilizers to improve the yield of marigolds, which increases the cost of production.

Organic sources of nutrients boost crop output and soil health by encouraging beneficial microorganisms, stimulating development, and reducing micronutrient deficiencies (Hegazi et al., 2007). In addition to providing nutrients that meet the demands of plants, organic liquid fertilizer may be applied more uniformly, and its concentration can be controlled to meet these needs (Ginandjar et al., 2019). Liquid organic fertilizers have outstanding effects on the physical, chemical, and biological properties of the soil and are inexpensive and simple to use (Kareem et al., 2022). Banana (*Musa* spp.) is one of Nepal's most significant fruit crops, providing around 24.3% of the country's total fruit production and is in high demand all year (Joshi et al., 2019). Farmers often discard pseudo-stems in fields after harvesting bananas (Sharma et al., 2017). Banana plants primarily produce sap in their pseudo-stems (which makes up 85 % of their total fluid volume), which can be collected for use as an efficient organic liquid fertilizer (Cao et al., 2018).

Biochemicals such as gibberellic acid, Naphthalene Acetic Acid (NAA), cytokinin, macronutrients (N, P, K, Ca, Mg, S), micronutrients (Mn, Cu, and Zn), and helpful bacteria such as phosphate-solubilizing bacteria (PSB), Rhizobium, Azotobacter, and fungus, are all present in the enriched sap of the banana pseudo-stem (Desai et al., 2020). This nutrient-enriched sap is a naturally occurring and affordable fertilizer that can be applied to plants as a foliar spray to promote plant growth and productivity (Fernando & Karunarathna, 2020). The pseudo-stem has a large amount of macronutrients compared to other portions of the banana plant (Islam et al., 2022). Similarly, it contains several phytochemicals based on genotypic variation, age (developing and developed plant), and plant parts in which it is located (Deng et al., 2020). The application of sap could generate Recommended Dose of Fertilizers (RDF) savings of between 20 and 40 percent without affecting the yields of bananas, sugarcane, and other crops (Kalariya et al., 2018). Until now, very little research has been done, and there is a huge knowledge gap regarding the effectiveness and

use of banana pseudo-stem sap as an organic liquid fertilizer in Nepal. Considering these factors, the current fieldwork in Rampur-Chitwan was investigated. The primary goal of this study is to determine the efficacy of enriched banana pseudo-stem sap in increasing the yield-attributing properties of marigold.

Nutritional and biochemical composition of banana pseudo-stem sap are listed in Table 1.

Table 1. Nutritional and biochemical composition of banana pseudo-stem sap ready to use

Macro and micro-nutrients present in banana pseudo-stem sap			Biochemical		
Parameters	Unit	Mean	Parameters	Unit	Content
N	%	0.62	Total Phenols	Mg 100 ⁻¹ ml ⁻¹	48.0-49.1
P		0.018	Urease activity	U ml ⁻¹ min ⁻¹	63-81
K		0.180	Gibberellic Acid	Mg l ⁻¹	110.2-205.0
Ca		0.031	Cytokinin	Mg l ⁻¹	137.8-244.3
Mg		0.092	Microbe	Unit	Population
S		0.010	Total viable count	(CFU ml ⁻¹)	1.065*10 ⁶
Mn	ppm	5.73	PSB		1.025*10 ⁵
Cu		0.40	Rhizobium		2.85*10 ⁴
Zn		2.92	Azotobacter		4.60*10 ⁴
Fe		109.3	Fungal count		1.2*10 ³

Source: (Desai et al., 2020)

2. Materials and methods

2.1 Research site and weather data

A field experiment was conducted from July 20 to November 5, 2022, at the Department of Horticulture, Agriculture and Forestry University Rampur, Chitwan, Nepal. The study site was situated at latitude 27 ° 37' N and 84 ° 25' E and was 228 m above the mean sea level. Soil properties range from silty loam texture to slightly acidic pH (6.5). The experimental site is illustrated in Figure 1. The weather conditions at the experimental site during the study period are given in Figure 2.

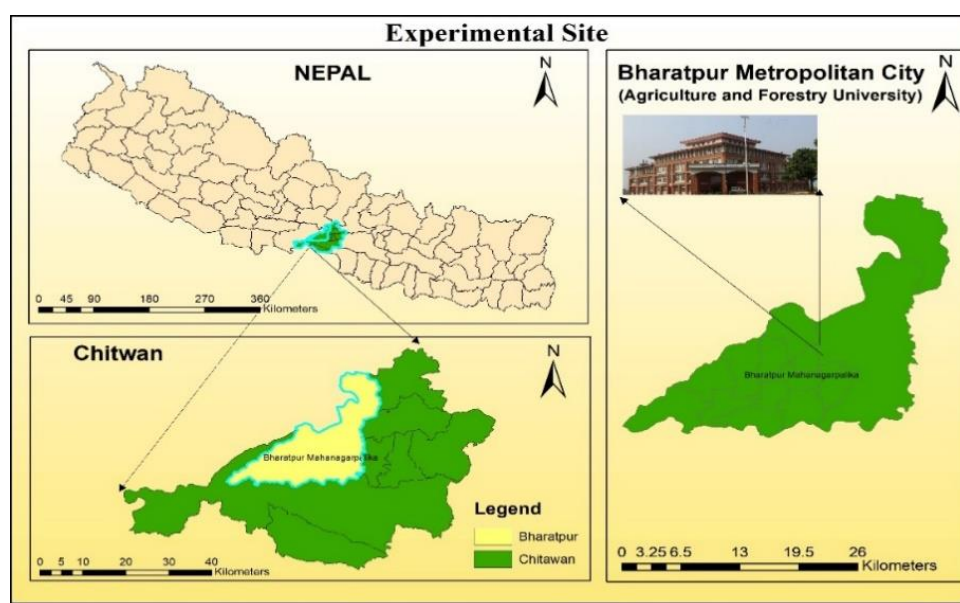


Figure 1. Experimental site

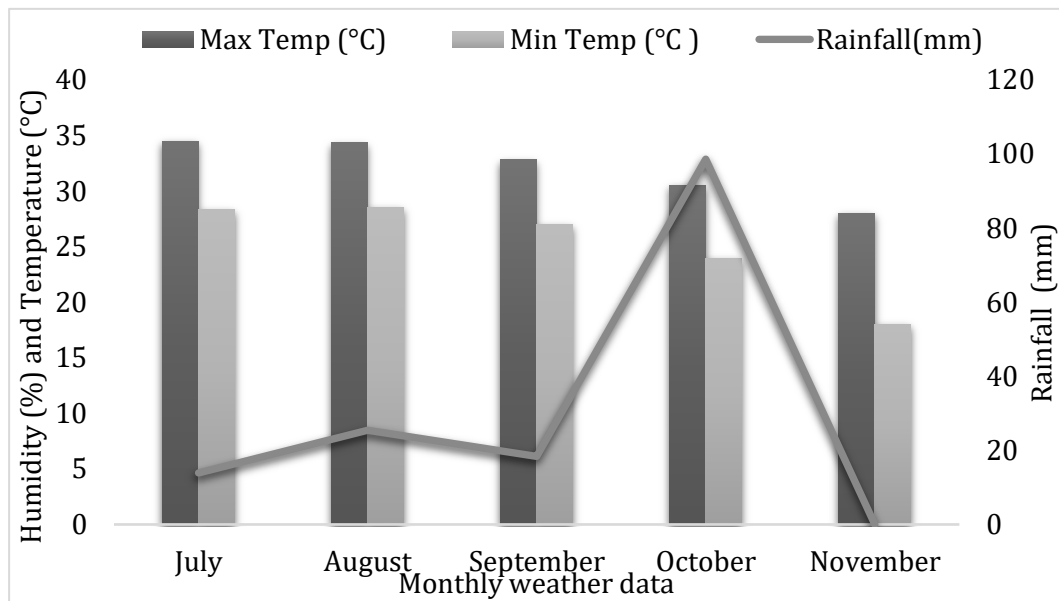


Figure 2. Climate chart of experimental site during cropping period

2.2 Experimental design and treatments

The experiment was laid out in a single-factorial Randomized Complete Block Design (RCBD) with three replications and seven treatments. The African marigold variety 'Karma 555 - Orange' was taken under study. The unit plot measured 3.2 m x 3 m (9.6 m²). The entire experimental plot was divided into three blocks, each consisting of seven plots. Each plot contained five rows of plants and each row contained four plants. Twenty plants were maintained per plot. Five plants were sampled in the middle of the plot (Aung & Zar, 2023). The plot-to-plot distance was 50 cm and the block-to-block distance was 100 cm. Seedlings were prepared in raised bed nurseries and transplanted on July 3, maintaining a spacing of 60 cm and 80 cm from plant to plant and row to row, respectively. The details of the treatment are presented in Table 2. The sample plants in the controlled plot were sprayed with water with 0% application of enriched pseudo-stem sap to test and compare the efficacy of enriched sap on yield components of marigold.

Table 2. Different treatments used in the experiment

Treatment number	Treatment name	Dose
T1	Banana pseudo-stem sap	0.5 %
T2	Banana pseudo-stem sap	1 %
T3	Banana pseudo-stem sap	2 %
T4	Banana pseudo-stem sap	3 %
T5	Banana pseudo-stem sap	4 %
T6	Banana pseudo-stem sap	5 %
T7	Water spray (control)	0 %

2.3 Preparation of nutrient-enriched liquid fertilizer

Banana pseudo-stem sap was collected from the mature and native-seeded banana (*Musa acuminata* L.) a wild ancestor of domestic banana plants. Pseudo-stems were obtained from an 11-month-old mature banana plant from the Department of Horticulture, Agriculture and Forestry University, Rampur, Chitwan, Nepal. The gathered pseudo-stem was unwrapped, and the rotten-infected sheath was removed. The leaf sheath and central core of the pseudo-stem were then chopped into small pieces (5-10 cm). The chopped pieces were then crushed into paste using a

mixer grinder with distilled water. The chopped paste was squeezed in a muslin cloth, and the extraction was filtered. Five liters of filtered banana pseudo-stem sap was then mixed with cow dung (250 g) as a microbial energy source, cow urine (125 ml) as a urease activity promoter, chopped green gram, neem leaves (250 g) as a carbon and nitrogen source, and fermented curd (125 g) as a *Lactobacillus* source. Similarly, vermin liquor (5 ml) was mixed as a growth booster, pulse flour (5 g) as a microbial activity enhancer, and jaggery (5 g) as an energy source in filtered sap (Kolambe et al., 2013). The combined mixture was incubated in a dark room under anaerobic conditions for 30 days. The mixture was checked regularly and stirred. After a specific period, the supernatant was collected, filtered, and stored in an airtight container. Hence, an enhanced banana BPS was prepared using different ingredients in a specific amount. In this experiment, 50 ml, 100 ml, 200 ml, 300 ml, 400 ml, and 500 ml of banana pseudo-stem sap were measured using a measuring cylinder and dissolved in 10 liters of water to prepare 0.5 %, 1.0 %, 2 %, 3 %, 4 %, and 5 % concentrations, respectively. The details of the ingredients used for the preparation of the enriched BPS are shown in Figure 3.

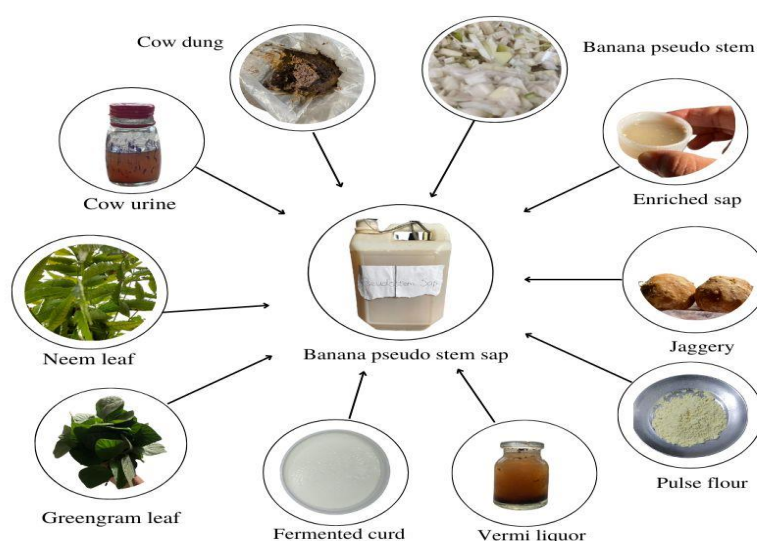


Figure 3. Ingredients used for the preparation of enriched banana pseudo-stem sap

2.4 Management practices

26-day-old seedlings with 3-4 leaves were planted according to the treatment combinations throughout the experiment. Manure and fertilizers were applied at the recommended dose of 20 tons of farmyard manure and 200:100:100 kg NPK ha⁻¹. A half dose of nitrogen and a full dose of P and K were applied as basal doses, and the remaining half dose of nitrogen was applied during the top dressing 35 days after transplanting. Regular hand weeding was performed to keep the plots free of weeds. Irrigation was performed immediately after fertilization. Pinching was performed 15 days after transplanting using sterilized scissors.

2.5 Observation and data collection

Five plants from each plot were chosen at random from the previously identified plants and marked as sample plants to record the data. The first spraying of the enriched banana pseudo-stem was performed 45 days after transplanting. Subsequently, regular spraying was performed every 15 days. Spraying was performed during the vigorous growth, bud burst, and flowering stages. Vegetative and reproductive data were collected every five days after spraying. During the initial phase, data on plant height, spread, primary branch count, days to bud initiation, and days

to flowering were recorded. After the first flower harvest, harvesting was performed at intervals of approximately one week. The yield and yield attributes, such as the number of flowers per plant, individual flower diameter, individual flower weight, and flower yield per plant, were noted at the final harvest. The following characteristics were studied during the successive plant growth stages.

Plant height (cm)

The height of the tagged plants was measured from the soil surface to the highest points at which the petioles of the two youngest leaves touched and to the tip of the flower at harvest using a ruler (Mohammadipour et al., 2012; Gonge et al., 2015).

Plant spread (cm)

Plant spread was calculated by measuring the east-west spread and north-south spread of plants and averaging their values (Sagvekar et al., 2019). It helps to determine the number of branches and has significant impact in yield components.

Number of flowers per plant

The total number of flowers per plant was determined by collecting the number of flowers from tagged plants through visual counts. The total number of flowers was counted periodically at 70 and 90 DAT and the average number of flowers produced per plant was calculated.

Individual flower diameter (cm)

In each plot, 15 flowers were randomly chosen from the sample plants, and the average diameter of the chosen flowers was calculated using a Vernier caliper.

Individual flower weight (g)

Flowers were plucked randomly from the sample plants in the morning when the central whorl of the petals was fully opened. The flowers were shade-dried for approximately an hour and the data for the average weight of individual flowers per plant were obtained by measuring the analytical balance.

Days to bud initiation

The total number of days taken for bud initiation was recorded by counting the number of days from the date of marigold transplantation.

Days to first flowering

The days for the first flowering of marigolds were observed in each treatment at the 100 % petal unfold stage, and the mean data were calculated.

Flower yield (g plant⁻¹)

The yield was recorded by weighing the flowers harvested from three different pickings. The total weight of all the flowers picked from a single plant during the season yielded the yield per plant.

2.6 Statistical analysis

The data extracted from the experimental plots of numerous parameters were statistically examined to determine the relevance of the treatments using the standards of the experimental design. The obtained data were entered, tabulated, and analyzed using Microsoft Excel-2016. The means of the data were separated using Duncan's Multiple Range Test at a significance level of 0.05, and data were statistically examined by performing an analysis of variance (ANOVA) using R-Studio version 4.2.2.

3. Results and discussion

3.1 Vegetative parameters

Compared to the control plots, the observed data analysis suggests that the foliar spray of various concentrations of banana pseudo-stem sap significantly affected most of the examined growth and vegetative parameters of marigolds. All expressed parameters increased with increasing doses of pseudo-stem sap and decreased with 4 % BPS and 5 % BPS, respectively.

Plant height

The effect of different concentrations of banana pseudo-stem sap on marigold plant height is shown in Table 3. Mean plant height was not significantly influenced by the pseudo-stem sap at 50 DAT. Significant differences were observed in plant height between different concentrations of pseudo-stem sap treatments and the control at 70 and 90 DAT. Plant height was found to be a significant ($p < 0.05$) level of significance at 90 DAT. The average plant height was highest at 3 % BPS (68.13 cm) at 90 DAT, followed by 4 % BPS (81.07 cm) and 5 % BPS (74.82 cm) at the final harvest. Similarly, the minimum plant height (66.78 cm) was recorded in the water spray (control) plot. At 90 DAT, 0.5 % BPS (71.27 cm), 1 % BPS (69.13 cm), and 2 % BPS (72.57 cm) were found statistically at par with each other. This increase in plant height may be the result of increased meristematic activity caused by improved cell division and cell elongation due to increased auxin levels in the tissue or conversion of tryptophan to Indole Acetic Acid (IAA) by enriched pseudo-stem sap Desai et al. (2020). An increase in plant height by the application of banana pseudo-stem sap has been recorded by Jadhav et al. (2014) in marigolds. This could be induced by nitrogen, which is found in the pseudo-stem sap and is essential for cell formation, growth, and development as well as for accelerating the production of chlorophylls, which are essential for the primary photosynthesis process of plants and enhance the development of meristematic tissues Chotaliya et al. (2018). The enhanced plant height was caused by greater cell division and elongation at higher levels of N because of the significant effects of enriched BPS in cowpea Singhal et al. (2015). This result is also in agreement with the findings reported by Patel et al. (2017) for the green gram.

Table 3. Effects of foliar spray of enriched BPS on plant height

Treatment	Plant height (cm)		
	50 DAT	70 DAT	90 DAT (At harvest)
0.5 % BPS	33.87 ^a	58.00 ^{ab}	71.27 ^{cd}
1 % BPS	28.47 ^a	49.97 ^b	69.13 ^{cd}
2 % BPS	31.13 ^a	56.53 ^{ab}	72.57 ^{cd}
3 % BPS	31.27 ^a	68.13 ^a	85.07 ^a
4 % BPS	34.07 ^a	63.13 ^{ab}	81.07 ^{ab}
5 % BPS	33.73 ^a	55.13 ^{ab}	74.82 ^{bc}
Control	29.30 ^a	52.30 ^b	66.78 ^d
LSD (0.05)	11.34	12.28	7.04
SE _m ($\pm$)	2.98	3.22	1.85
F-Test	0.38	2.47	8.22 ^{**}
CV, %	20.11	11.98	5.32
Grand Mean	31.69	57.60	74.39

Means within the column followed by the same letter are not significantly different at the 5 % level of significance by DMRT. *Significant at 10 % ($p < 0.10$), ** significant at 5 % ($p < 0.05$), and *** significant at 1 % ($p < 0.01$), and SEM= Standard Error of Mean, LSD= Least Significant Difference, and CV= Coefficient of Variation

Plant spread

The analysis of variance on the plant spread of marigolds showed a significant result ($p < 0.05$) at 50 DAT and 90 DAT, respectively, and significant at 70 DAT ($p < 0.10$). Plant spread was found to be significant at all growth stages. Maximum plant spread was observed at 3 % BPS (23.10 cm), (35.35 cm), and (63.47 cm) at 50, 70, and 90 DAT, respectively. Plant spread of 4 % BPS (58.13 cm) and 5 % BPS (58.87 cm) was statistically at par with that of 3 % BPS (63.47 cm) at 90 DAT. The minimum plant spread was recorded at 0.5 % BPS (48.40 cm), which was similar to that of the control plot (48.97 cm), as shown in Table 4. This might be because nitrogen is an essential component of nucleic acids, which play an important role in promoting plant development. Similarly, phosphorus is a component of chlorophyll and is involved in a variety of physiological processes, such as cell division, meristematic tissue formation, photosynthesis, and glucose, lipid, and protein metabolism [Dikr and Belete \(2017\)](#). The maximum plant spread might be linked to an increase in tissue auxin levels or an increase in the conversion of tryptophan to IAA, resulting in increased cell division and cell elongation via the effects of gibberellic acid and cytokinin alone or a combination of both [Gawade et al. \(2019\)](#). This could be because enriched BPS contains bio-inoculants (*Azotobacter* and PSB), which are beneficial for fixing atmospheric nitrogen and solubilizing fixed phosphorus in the soil, as well as secreting growth substances, such as auxins, which stimulate plant metabolic activities and photosynthetic efficacy, resulting in better plant growth and development [Kumar et al. \(2009\)](#). The variation in plant spread was due to the increase in plant height and number of branches. [Kumar et al. \(2010\)](#) reported that increased plant spread was due to an increase in the concentration of GA_3 . A similar result was obtained by [Khanal et al. \(2015\)](#) for the gladiolus.

Table 4. Effects of foliar spray of enriched BPS on plant spread

Treatments	Plant spread (cm)		
	50 DAT	70 DAT	90 DAT (At harvest)
0.5 % BPS	18.43 ^b	24.43 ^d	48.40 ^b
1 % BPS	18.23 ^{bc}	30.77 ^{abc}	59.03 ^a
2 % BPS	20.63 ^{ab}	28.67 ^{bcd}	56.10 ^{ab}
3 % BPS	23.10 ^a	35.35 ^a	63.47 ^a
4 % BPS	21.70 ^a	31.33 ^{ab}	58.13 ^a
5 % BPS	18.87 ^b	30.67 ^{abc}	58.87 ^a
Control	15.53 ^c	25.10 ^{cd}	48.97 ^b
LSD (0.05)	2.73	5.35	7.46
SE _m ($\pm$)	0.72	1.41	1.96
F-Test	8.05**	4.76*	5.25**
CV, %	7.88	10.21	7.47
Grand Mean	19.50	29.47	56.14

Means within the column followed by the same letter are not significantly different at the 5 % level of significance by DMRT. *Significant at 10 % ($p < 0.10$), ** significant at 5 % ($p < 0.05$), and *** significant at 1 % ($p < 0.01$), and SEM= Standard Error of Mean, LSD= Least Significant Difference, and CV= Coefficient of Variation

Primary branches

The primary branches showed significant effects at the ($p < 0.01$) level of significance when different concentrations of enhanced BPS were sprayed foliar. The highest number of primary branches (eight) was observed in 3 % BPS, followed by 4 % BPS (seven), and 2 % BPS (seven). The lowest number of branches was seen in 0.5 % BPS and 1 % BPS, which were statistically at par with the control plot (five), as shown in Table 5. BPS-enriched sap contains vital plant nutrients, growth regulators such as GA_3 and cytokinin, and trace amounts of minerals, all of which

promote plant growth and increase the number of branches per plant [Jadhav et al. \(2014\)](#). An ample amount of micronutrients and nitrogen in pseudo-stem sap makes plant roots more effective at absorbing other nutrient ions, such as phosphorus and potassium, which aids in the termination of vegetative growth, resulting in more branches [Champaneri et al. \(2021\)](#). Similar results were reported by [Chaurasia et al. \(2005\)](#) for tomatoes.

Days to bud initiation

The analysis of days to bud initiation for marigolds showed a significant result at the ($p < 0.01$) level of significance. Statistically significant differences were observed between treatment and control groups. 5 % BPS (53.00 days) required the minimum number of days for bud initiation, whereas the control plot required the maximum time (67.00 days) for bud initiation compared with the other plots. Plants sprayed with 1 % BPS (57.00 days), 2 % BPS (57.00 days), and 4 % BPS (55.00 days) were statistically at par with each other. This may be the result of gibberellins shortening the juvenile phase and conversion of the apical meristem into flowering primordia rather than the production of leaves at the time of juvenile phase determination [Wagh et al. \(2012\)](#). BPS contains GA₃, which stimulates plant physiological activities, resulting in early maturity [Rathod et al. \(2017\)](#).

Days to first flowering

Days to first flowering were found to be significant at ($p < 0.01$) level of significance in the treatment with different levels of pseudo-stem sap throughout the growth period. Plots treated with 3 % BPS took (63.00 days) for flowering whereas 4 % BPS (59.00 days) and 5 % BPS (58.00 days) took nearly less time to bloom. The controlled plot took a maximum of (71.00 days) for flowering. This outcome could be explained by the possibility that gibberellic acid's conversion of the apical meristem to floral primordia ensures a steady supply of nourishment from leaves throughout flowering, which prolongs floral longevity [Singh and Karuna \(2011\)](#). The shortened flower development period could be because enhanced BPS is a source of macro-and micronutrients that play an important role in increasing physiological activities such as chlorophyll synthesis, which may assist in the production of a large amount of biomass, leading to early flower development [Christian et al. \(2022\)](#).

Table 5. Effects of different concentrations of enriched BPS on primary branches, bud initiation, and days for first flowering

Treatments	Primary branches	Days for bud initiation	Days for first flowering
0.5 % BPS	5.00 ^d	62.00 ^b	67.00 ^b
1 % BPS	5.00 ^d	57.00 ^{cd}	62.00 ^{cd}
2 % BPS	7.00 ^b	57.00 ^{cd}	62.00 ^{cd}
3 % BPS	8.00 ^a	58.00 ^c	63.00 ^c
4 % BPS	7.00 ^{ab}	55.00 ^{cd}	59.00 ^{de}
5 % BPS	6.00 ^{bc}	53.00 ^d	58.00 ^e
Control	5.00 ^{cd}	67.00 ^a	71.00 ^a
Grand Mean	6.14	58.42	63.14
LSD (0.05)	0.99	3.76	2.63
SE _m (±)	0.26	0.99	0.69
F-Test	13.15***	15.04***	29.09***
CV (%)	9.05	3.61	2.35

Means within the column followed by the same letter are not significantly different at a 5 % level of significance by DMRT. *Significant at 10 % ($p < 0.10$), ** significant at 5 % ($p < 0.05$), and *** significant at 1 % ($p < 0.01$), and SEM= Standard Error of Mean, LSD= Least Significant Difference, and CV= Coefficient of Variation

3.2 Reproductive parameters

Different yield-attributing parameters, such as the number of flowers per plant, individual flower weight, individual flower diameter, and flower yield, were found to be significant among the foliar spray of different treatment combinations of enriched BPS.

Number of flowers per plant

The analysis of variance (Table 6) showed that different concentrations of foliar spray of pseudo-stem sap had significant effects on the number of flowers per plant. The number of flowers per plant was significantly different between treatments ($p < 0.05$) level of significance. The highest number of flowers was recorded with 3 % BPS (74.00), followed by 4 % BPS (72.00). Plots sprayed with 0.5 % BPS had the lowest number of flowers per plant (64.00), which was at par with the control plot (66.00). The presence of macro-and micronutrients, as well as growth regulators, in the pseudo-stem sap may explain the increase in the number of flower buds per shoot. As a result, the plants remain physiologically more active to build up sufficient food stock for growing flowers by producing a favorable C: N ratio in the terminals, resulting in an increased number of flower buds per stem [Christian et al. \(2022\)](#). Increased cell division and elongation with GA₃ and decreased levels of Butyric Acid (BA) and Naphthalene Acetic Acid (NAA) may be the reasons for the increase in the number of flowers per plant [Kumar and Gautam \(2011\)](#). This could be because plants store more carbohydrates early in their growth, which improves the supply of nutrients, resulting in a higher number of flowers and yield per plant [Patil et al. \(2017\)](#). An increased number of flowers per plant and flower yield per plot was reported by the drenching of BPS in marigolds [Jadhav et al. \(2014\)](#). A similar result was obtained by [Patel et al. \(2018\)](#), who recorded the maximum fruit retention (%) at harvest and the number of fruits per panicle in mango.

Individual flower weight

The individual flower weights showed highly significant differences among the treatments at a ($p < 0.01$) level of significance. The maximum flower weight occurred in 3 % BPS (8.10 g), followed by 4 % BPS (7.64 g), and 2 % BPS (7.31 g). The lowest flower weight was recorded in the plot sprayed with 1 % BPS (6.66 g), which is at par with the control plot (6.69 g). A greater supply of nutrients at the critical stage of flowering may have increased the use of photosynthates and their allocation to the economic part of the process, increasing flower weight and eventually yield per plant [Batra et al. \(2006\)](#). The increase in weight might be due to the supply of more nutrients (NPK) through foliar spraying at the critical growth stage [Chaurasia et al. \(2005\)](#). Similarly, [Patil et al. \(2017\)](#) also recorded the highest bunch weight and weight of the third hand of banana with 1 % foliar spray of BPS.

Individual flower diameter

The different concentrations of BPS foliar spray of BPS has significant effects on individual flower diameter. The average diameter of a flower was found significant at ($p < 0.01$) level of significance. The maximum flower diameter occurred in the plot sprayed with 3 % BPS (7.55 cm), followed by 2 % BPS (7.06 cm), 4 % BPS (6.57 cm), and 5 % BPS (6.41 cm). The control plot resulted in a minimum diameter of the flower (4.52 cm). Plots treated with 1 % BPS (6.09 cm) and 5 % BPS (6.41 cm) were statistically similar. Since BPS contains macro-and micronutrients, as well as growth-promoting compounds that induce plant overall growth, the total yield may be attributable to the larger production of dry matter, resulting in increased weight and diameter of flowers, resulting in higher yield per plant [Kalariya et al. \(2018\)](#). This result is consistent with the findings of [Parmar et al. \(2020\)](#). This might be due to higher carbohydrate buildup in the plant during the early stages of growth, resulting in improved nutritional delivery, which causes an increase in fruit size and, as a result, an increase in average fruit weight in terms of length and diameter. Bud and flower diameters were found to be significantly affected by 2 % BPS in roses [Singh et al. \(2022\)](#). Similar findings were observed by [Rathod et al. \(2017\)](#) for pomegranates.

Flower yield

Statistically significant differences were observed between different concentrations of BPS and the control in terms of flower yield per plant. The flower yield for different treatment doses of the BPS foliar spray was found to be significant ($p < 0.01$) level of significance. The highest yield was observed with 3% BPS (597.25 g), followed by 4% BPS (547.34 g). The lowest yield was recorded in the plot sprayed with 0.5% BPS (434.67 g). 2% BPS (521.28 g), 4% BPS (547.34 g), and 5% BPS (509.87 g) were found statistically at par with each other. Higher yield may be attributable to the ease of nutrient absorption, the NPK ratio's balance, and the micronutrients found in the pseudo-stem sap, which have an impact on crop productivity (Singhal et al., 2015). Spraying water-soluble nutrients promotes nutrient uptake and water intake, combined with nutrient accessibility, leading to increased photosynthesis and improved food accumulation in edible portions (Champaneri et al. (2021)). In addition, most vital minerals, particularly nitrogen and potassium, are present at higher concentrations in banana pseudo-stem sap, which eventually promotes growth, yield, nutritional content, uptake, and availability (Salunkhe et al. (2013)). Enhanced BPS boosted flower yield because of the high quantity of potash and moderate levels of N, P, Ca, Mg, S, Zn, and B with GA3, cytokinin, amino acids, and phenol (Patel et al., (2018)), including trace amounts of critical nutrients and growth factors, which are known to improve crop fruiting metrics (Rathod et al. (2017)). This result is in agreement with the findings of (Patil et al. (2014)). The relationship between different BPS treatments and yield is shown in Table 6.

Table 6. Effects of different concentrations of enriched BPS on yield attributing parameters of African marigold

Treatments	Flowers per plant	Individual flower weight (g)	Individual flower diameter (cm)	Flower yield (g plant ⁻¹)
0.5 % BPS	64.00 ^c	6.71 ^d	5.34 ^{cd}	434.67 ^c
1 % BPS	66.00 ^{bc}	6.66 ^d	6.09 ^{bc}	446.93 ^c
2 % BPS	71.00 ^{ab}	7.31 ^{bc}	7.06 ^{ab}	521.28 ^b
3 % BPS	74.00 ^a	8.10 ^a	7.55 ^a	597.25 ^a
4 % BPS	72.00 ^{ab}	7.64 ^b	6.57 ^{ab}	547.34 ^b
5 % BPS	71.00 ^{ab}	7.07 ^{cd}	6.41 ^{bc}	509.87 ^b
Control	66.00 ^{bc}	6.69 ^d	4.52 ^d	451.22 ^c
Grand Mean	69.14	7.17	6.22	501.22
LSD (0.05)	4.29	0.45	1.04	46.83
SE _m (±)	1.13	0.12	0.27	12.29
F-Test	6.70**	13.95***	9.24***	15.66***
CV (%)	3.48	3.56	9.39	5.25

Means within the column followed by the same letter are not significantly different at a 5 % level of significance by DMRT. *Significant at 10 % ($p < 0.10$), ** significant at 5 % ($p < 0.05$), and *** significant at 1 % ($p < 0.01$), and. SEM= Standard Error of Mean, LSD= Least Significant Difference, and CV= Coefficient of Variation

Conclusion

This study showed that BPS has a major impact on growth and yield. The foliar spray of different concentrations of BPS had a significant effect on the different studied parameters of the marigolds. Among the tested concentrations, 3 % BPS showed optimum performance across the observed parameters related to the yield and quality of the marigold. Plant height, plant spread, number of branches, and major reproductive factors, such as the number of flowers, individual flower weight, individual flower diameter, and flower yield per plant, showed significant variations between the different sap concentrations and the control. This could potentially be used for partial or full replacement of chemical nutrients in various flowers, fruits, and vegetables. The

ease of preparation of pseudo-stem sap makes it a cost-effective liquid organic fertilizer that is easily affordable for small-scale farmers. The ingredients needed for sap preparation are easily available in the Nepalese agro-ecosystem as well as in their home gardens. Therefore, foliar spraying of BPS is recommended for higher yield and better quality marigold flowers. This could help small-scale farmers in the sustainable and commercialized production of marigolds in the future. These findings can be further verified in other studies. It can be extended and tested in other varieties of marigolds as well as in other flowering plants. More studies must be conducted to prove its effectiveness in other crops, such as vegetables and fruits, to enable farmers to use it on a full time basis. Enrichment materials, effective mode of application, concentration of pseudo-stem sap, and the optimum time of application should be further studied.

The study was conducted in a single season and a single variety of marigolds. The quality and yield of the flowers could be checked and compared with the standard application of synthetic fertilizers and micronutrients in the same variety. Since the nutrient content of pseudo-stem saps of different genotypes of bananas varies among each other and could have significant differences in their effects on yield and yield attributing characters, further research trials should be conducted for finding out the most effective and convenient one.

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Authors' declaration and contribution

The authors state that they have no conflicts of interest. All authors participated equally to the creation of this work at all stages. Similarly, every author approved the final version of the work.

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