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Studies on split application of NPK fertilizers and liquid bio-formulation (Jeevamrutha) on yield and quality of pomegranate (*Punica granatum* L.) in central dry zone of Karnataka

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Abstract
A study was conducted in farmer's field at Chillahalli village, Hiriyur taluk, Chitradurga district during the year 2020-2021. The experiment was laid out in Randomized Complete Block Design comprising of seven treatments replicated thrice. Among fruit and yield parameters, fruit length (8.60 cm), fruit diameter (82.10 mm), fruit volume (369.38 cc), number of fruits per plant (63.95), average fruit weight (290.11 g), fruit yield (18.55 kg/plant) was maximum in 100 per cent RDF through split application along with jeevamrutha (T_7). The maximum TSS (16.24 °Brix), TSS : acid ratio (33.83), ascorbic acid (17.34 mg/100 ml), moisture content in arils (87.01%), juice content (81.16%), minimum acidity (0.48%) was observed in T_7. Therefore, 100 per cent RDF through split application along with jeevamrutha at different stages *i.e.*, 160:80:80 N: P_2O_5: K_2O g per plant from defoliation to flowering stage, 100:60:40 N: P_2O_5: K_2O g per plant from flowering to fruit set stage and 140:60:80 N: P_2O_5: K_2O g per plant at fruit development stage proved to be promising for fetching higher yield in pomegranate *cv*. Bhagwa.

Keywords: pomegranate, split application, jeevamrutha, Bhagwa, NPK

Introduction
Pomegranate (*Punica granatum* L.) belonging to the family Lythraceae is one of the favourite dollar earning table fruits of tropical and sub-tropical regions and also the oldest known edible fruit. Pomegranate is emerging as one of the most promising fruit crop owing to its hardiness and ability to withstand adverse soil and climatic conditions. Hence, this crop deserves tremendous scope for its cultivation in arid and semi-arid regions. In India pomegranate is cultivated in the states of Maharashtra, Gujarat, Karnataka, Andra Pradesh, Madhya Pradesh, Rajasthan and Tamilnadu. Maharashtra is the leading state in pomegranate cultivation. In Karnataka pomegranate is cultivated on an area of 25,970 hectares with an annual production of 2,68,230 tonnes (Anon., 2017-18) [1]. The major districts of Karnataka producing pomegranate are Belagavi, Vijayapura, Bagalkot, Koppal, Bellary and Chitradurga. This crop has spread to Tumkur, Kolar and Bengaluru rural districts in recent years.
Under subtropical conditions, pomegranate bears heavily which can exhaust the essential elements in soil needed for proper growth and development. To optimize the fertilizer use, the approach of split application of fertilizer plays a very important role in a nutrient management strategy. Single application of fertilizer leads to period of over-supply, more leaching losses and also period of under-supply. It may not be able to maintain optimum soil nutrient status at all the critical growth stages of crop. So, it is paramount important to determine the number of splits for fertilizer application in pomegranate.
Jeevamrutha is one such natural liquid bio-fertilizer prepared by mixing up cow dung with cow urine, jaggery, pulse flour and handful of soil. It promotes immense biological activity in soil and makes the nutrients available to crop. It also contains enormous amount of microbial load which multiply and acts as a soil tonic (Palekar, 2006) [17]. This inturn has a positive effect on yield and quality of the crops. The microorganisms such as nitrogen fixer, azotobacter, azospirillum and phosphorus solubilizing bacteria like *Pseudomonas fluorescence* and potash solubilizing bacteria like *Bacillus silicus* are present in the cow dung that is used to prepare jeevamrutha (Ramprasad *et al*., 2009) [18]. Nutrient composition of jeevamrutha formulation includes macro-nutrients like nitrogen, potassium and phosphorus (1.96%, 0.280

% and 0.173%, respectively) as well as magnesium (46 ppm) and copper (51 ppm) (Devakumar *et al*., 2014) [5].

Considering the dual efficiency of conjoint use of inorganic NPK fertilizers and liquid bio-formulation jeevamrutha at different growth stages at right time on yield and quality attributes, the present investigation on "Studies on split application of NPK fertilizers and liquid bio-formulation (Jeevamrutha) on yield and quality of pomegranate (*Punica granatum* L.) in Central Dry Zone of Karnataka" was taken up.

Material and methods

The experiment was carried out during 2020-21 in the farmer's field at Chillahalli village, Hiriyur taluk of Chitradurga district. The experimental site comes under Central Dry Zone (Zone-IV) of Karnataka and is situated at 13º 57' North latitude and 70° 37' East longitude at an elevation of 606.1 m above the Mean Sea Level. The experiment was conducted on nine year old pomegranate trees of cv. Bhagwa with seven treatments and three replications in Randomized Complete Block Design. The total number of trees included in experiment was 42 and were spaced at 3×3 m spacing. Treatments were as follows : T_1 : RDF - 400:200:200 N:P_2O_5:K_2O (g/plant), T_2 : 50% RDF through split application, T_3 : 75% RDF through split application, T_4 : 100% RDF through split application, T_5 : 50% RDF through split application + jeevamrutha, T_6 : 75% RDF through split application + jeevamrutha, T_7 : 100% RDF through split application + jeevamrutha

RDF (400:200:200 NPK g/plant) was split in 3 different growth stages:

Stages	Duration	Per cent nutrient per plant		
		N	P_2O_5	K_2O
Defoliation to flowering	1 month	40%	40%	40%
Flowering to fruit set	2 months	25%	30%	20%
Fruit development	4 months	35%	30%	40%

Imposition of treatments

Experimental plants were supplied with FYM @ 25 kg per plant at the beginning of the season and fertilizers were applied as per the treatment requirements. Recommende d dose of fertilizers 400:200:200 N: P_2O_5: K_2O gram/plant was adopted to carry out the experiment. Fertilizer doses were applied during the month of Dec - June. The recommended dose of nitrogen, phosphorous and potassium required for different treatments were supplied through fertilizers *viz.*, Urea (46-0-0), Di-ammonium phosphate (18-46-0) and Muriate of potash (0-0-60) through soil application at different growth stages (Plate 1.) after the defoliation. Fertilizers were applied through soil application by splitting N, P and K into two equal splits from defoliation to flowering, three equal splits from flowering to fruit set and four equal splits during fruit development stages. The bio-digested liquid (Jeevamrutha) was kept for fermentation for 72 hours and it was supplied through drip at the rate of 500 ml per plant at different growth stages to the treatments *viz.*, T_5, T_6 and T_7

a. Vegetative stage b. Flowering stage c. Fruit development stage

Plate 1: General view of the experimental plot at different growth stages

Observations recorded

The observations on yield parameters like number of fruits/plant, average fruit weight, fruit yield, fruit parameters like fruit length, diameter, volume and quality parameters like TSS, acidity, TSS:acid ratio, moisture per cent, juice per cent, ascorbic acid content were recorded. The data was analyzed statistically by following the procedure outlined by Fisher and Yates (1963) [8].

Results and Discussion

Yield parameters

The number of fruits per plant was significantly affected by various treatments of split application of NPK fertilizers, particularly higher level of potassium applied in split doses along with jeevamrutha application. Maximum number of fruits are formed in 100% RDF through split application + jeevamrutha (63.95). Application of 100% RDF through split along with jeevamrutha produced maximum fruit weight (290.11 g) and minimum (230.51 g) was recorded in T_1.The maximum fruit weight are most likely owing to continuous and balanced nutrient availability and uptake throughout the growing season having better capability for CO_2 assimilation, which would lead to higher rate of synthesis and supply of carbohydrates in plants. As fruits are strong sink for carbohydrates, more carbohydrates would be transported to the fruits leading to increase in fruit weight. Similar findings have been reported by Sheikh and Rao (2005) [21], Singh *et al* (2006) [23] and Rao and Subramanyam (2009) [19] in pomegranate.

Significant difference was observed among all the treatments in fruit yield (Table 1). The maximum fruit yield was observed in 100% RDF through split application + jeevamrutha (18.55 kg/plant), while the minimum was noticed in T_1 (12.48 kg/plant) (Plate 2.). The increase in yield was largely as a consequence of maximum fruit number and fruit weight. Apart from this, supply of sufficient amount of

nutrients through split application of NPK fertilizers restricts the fluctuation in nutrient status within narrow range leading to higher yield. Higher number of split application has resulted in proper supply and translocation of nutrients throughout the vegetative growth, flowering and fruiting stage. These factors might have enhanced fruit yield.

Also beneficial effect of jeevamrutha might be attributed to the availability of sufficient amounts of plant nutrients throughout the growth period especially at critical growth periods of crops resulting in better uptake, plant vigour and superior yield attributes. The results were in accordance with Khehra and Bal (2015) in lemon and Khan *et al.* (2018) in guava, Nadkarni *et al.* (2018) [15] in pomegranate and Anusha *et al.* (2021) [2] in sapota.

Table 1: Effect of split application of NPK fertilizers and jeevamrutha on yield parameters of pomegranate

Treatments	Number of fruits per plant	Average fruit weight (g)	Fruit yield (kg/plant)
T_1 - RDF - 400:200:200 N:P_2O_5:K_2O g/plant	54.10	230.51	12.48
T_2 - 50% RDF through split application	55.30	235.35	13.04
T_3 - 75% RDF through split application	57.10	250.20	14.29
T_4 - 100% RDF through split application	60.19	266.15	16.02
T_5 - 50% RDF through split application + jeevamrutha	57.95	252.95	14.83
T_6 - 75% RDF through split application + jeevamrutha	61.10	268.31	16.40
T_7 - 100% RDF through split application + jeevamrutha	63.95	290.11	18.55
S.Em ±	1.00	5.36	0.32
C.D. @ 5%	3.09	16.69	0.99

RDF - 400:200:200 N:P_2O_5:K_2O g/plant (T_1) 100% RDF through split application + jeevamrutha (T_7)

Plate 2: Effect of 100% RDF through split application + jeevamrutha on fruit yield over control (RDF)

Fruit parameters

The fruit size (length, diameter and volume) indicate that the different levels of NPK influenced the fruit size significantly (Table 2.). Among all the treatments, the maximum fruit size was noted with 100% RDF through split application + jeevamrutha (8.60 cm, 82.10 mm and 359.63 cc). Larger fruit size under this treatment might be due to the fact that jeevamrutha being the rich source of plant growth substances like auxins, gibberlic acid and cytokinin is involved in increasing cell size, cell elongation and cell division contributing to increase in fruit length, diameter and volume. These findings are in line with Negi (2018) [16] and Kirankumar *et al.* (2018) [14] in pomegranate, Kaur and Kaur (2017) [11] in guava. It was also noted that increased potassium rates along with moderate levels of nitrogen and phosphorous during fruit development stage is known to regulate the transpiration and water conductance in plant cells, thereby increasing the photosynthetic activity which in turn cause greater synthesis, translocation and accumulation of carbohydrates producing larger size fruits. The results are in conformity with Dhillon *et al.* (2011) [6], Sheikh and Rao (2005) [21] in pomegranate and Khan *et al.* (2018) [13] in guava.

Table 2: Effect of split application of NPK fertilizers and jeevamrutha on fruit parameters of pomegranate

Treatments	Fruit length (cm)	Fruit diameter (mm)	Fruit volume (cc)
T_1 - RDF - 400:200:200 N:P_2O_5:K_2O g/plant	5.91	56.20	250.22
T_2 - 50% RDF through split application	6.34	60.15	250.48
T_3 - 75% RDF through split application	6.86	68.18	267.15
T_4 - 100% RDF through split application	7.83	77.43	328.62
T_5 - 50% RDF through split application + jeevamrutha	7.01	69.26	299.95
T_6 - 75% RDF through split application + jeevamrutha	8.49	79.42	359.63
T_7 - 100% RDF through split application + jeevamrutha	8.60	82.10	369.38
S.Em ±	0.16	1.51	6.61
C.D. @ 5%	0.48	4.66	20.36

Quality parameters

Total soluble solids (TSS), acidity and TSS to acid ratio (Table 3.) were significantly distinct among the treatments. Application of 100% RDF through split along with jeevamrutha showed highest total soluble solids and TSS to acid ratio (16.24 °Brix and 33.83%) and the same treatment showed minimum acidity (0.48%). While, T_1 recorded lowest TSS and TSS to acid ratio (13.94 °B and 19.63%).

Pomegranate fruit quality is determined primarily by total soluble solid content, acidity and nutritional content particularly ascorbic acid. During the fruit development stage, an increase in potassium level leads to significant rise in TSS. Potassium is known to aid in the metabolic conversion of starch and pectin into soluble compounds, as well as the rapid translocation of sugars from leaves to maturing fruits, hence its uptake in the fruit enhanced sugar content and TSS. The acidity was lowered by increasing the potassium content. This could be owing to the tissues with high K^+ levels neutralising the organic acids. Increase in TSS : Acid ratio is caused by decrease in acidity and increase in TSS contents of fruits which contributed to the fruit flavour. Similar findings were obtained by Balamohan *et al.* (2015) [3] in banana, Singh and Varu (2013) [22] in Papaya.

Supply of higher dose of fertilizers in split maximized the growth of the plant and facilitated in accumulation of more carbohydrates into the fruit during the subsequent fruit development stage. Such metabolites (starch) will hydrolyze into sugar that increases the TSS and decrease the acidity. (Haneef *et al*., 2014 in pomegranate)

Improved fruit quality could be attributed to the constant supply of nutrients specially potassium, higher concentrations of soil enzymes, soil microorganisms, rapid mineralization and transformation of plant nutrients in soil and also growth promoting substances produced by microorganisms as a result of the addition of jeevamrutha to the soil, which may have aided in the biosynthesis and translocation of carbohydrates into the fruit. These results elucidate the findings of Vanilarasu and Balakrishnamurthy (2014) [25] in banana, Chandra *et al.* (2016) [4] and Sahu *et al.* (2017) [20] in guava.

The results showed that varied doses of NPK fertilizers and jeevamrutha had a substantial impact on moisture content and juice content with 100 per cent RDF by split application + jeevamrutha (87.01%, 81.16%) having the highest impact and T_1 (80.84%, 76.21%) having the lowest. Higher level of moisture content of arils may be attributed to higher moisture retention in soil and higher uptake of moisture and nutrients like 'K' by the plant tissue due to biofertilization (Jeevamrutha). This ample availability of water in plant tissue may have resulted in higher moisture content in arils of pomegranate. Since, water is the chief constituent of fruit juice, increasing its availability within specific limits was likely to have a positive impact on the juice percentage. The results are in conformity with Jhade *et al.* (2020) [10] in papaya and Khehra and Bal (2016) [12] in lemon.

Significant differences were noticed among the different treatments in ascorbic acid content (Fig. 4). The maximum ascorbic acid content (17.34 mg/100ml) was recorded in 100% RDF through split application + jeevamrutha. The increase in ascorbic acid under application of 100% RDF through split along with jeevamrutha may be due to the improved soil health and enhanced nutrient availability, enzymes, growth hormones and other minerals essential for growth and development by enhancing the capacity of plant for better uptake of nutrients from rhizosphere. The results are in line with Sahu *et al.* (2017) [20] in guava, Srinu *et al*. (2017) [24] in papaya and Balamohan *et al.* (2015) [3] in Banana and Dwivedi *et al.* (2010) [7] in guava.

Table 3: Effect of split application of NPK fertilizers and jeevamrutha on quality parameters of pomegranate fruit

Treatments	TSS (°Brix)	Acidity (%)	TSS: Acid ratio	Moisture content in arils (%)	Juice content (%)	Ascorbic acid content (mg/100ml)
T_1 - RDF - 400:200:200 N:P_2O_5:K_2O g/plant	13.94	0.71	19.63	80.84	76.21	14.71
T_2 - 50% RDF through split application	14.74	0.68	21.68	81.01	77.22	15.21
T_3 - 75% RDF through split application	14.91	0.63	23.67	82.34	77.93	15.32
T_4 - 100% RDF through split application	15.91	0.54	29.46	82.50	78.45	16.42
T_5 - 50% RDF through split application + jeevamrutha	15.54	0.58	26.79	84.01	79.88	15.88
T_6 - 75% RDF through split application + jeevamrutha	16.12	0.53	30.42	85.69	80.21	17.13
T_7 - 100% RDF through split application + jeevamrutha	16.24	0.48	33.83	87.01	81.16	17.34
S.Em ±	0.32	0.01	0.57	0.34	0.63	0.34
C.D. @ 5%	1.00	0.03	1.76	1.06	1.95	1.04

Conclusion

By considering the results obtained from the study, it can be concluded that 100% RDF through split application along with liquid bio-formulation (Jeevamrutha) at different growth stages *i.e.*,160:80:80 N:P_2O_5:K_2O g/plant from defoliation to flowering stage, 100:60:40 N:P_2O_5:K_2O g/plant from flowering to fruit set stage and 140:60:80 N:P_2O_5:K_2O g/plant at fruit development stage proved to be promising for fetching higher yield in pomegranate *cv.* Bhagwa in Hiriyur region of Chitradurga district in Karnataka. This study also demonstrated that inadequacy of one or the other nutrients at critical growth stages can be fulfilled with the use of liquid bio-formulation (Jeevamrutha) along with NPK fertilizers through split application.

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