Indian Journal of Agricultural Sciences **88** (1): 95–106, January 2018/Article

Crop load, fruit russeting, vegetative growth traits and leaf nutrient effects as a function of customized foliar nutritive fluids in Gale Gala apple (*Malus* × *domestica*) in dry temperate environment

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Received: 01 July 2017; Accepted: 25 August 2017

ABSTRACT

The study exploited the clonal rootstocks for bio-efficacy testing of water soluble customized nutrient (WSCN), viz. K_2O:S:Mg:Ca:Zn:B (6:11:5:0.3:0.3:0.4, w/w) on agronomic performance, fruit yield and quality characteristics on Gale Gala apple (*Malus* × *domestica* Borkh.) grafted onto EMLA.111 and EMLA.7 clonal rootstocks in dry temperate climatic conditions of north-west Himalaya. The trial procedure included tree fertilization of four levels of NPK soil fertilizers (100, 80, 60 and 40% of recommended dose of fertilizers (RDF-NPK, 70:35:70, one-year-old tree basis) were supplemented along with WSCN foliar formulation. Application of 60% RDF+75g WSCN+25g urea at 15 DAPF followed by 75g WSCN at 30 and 45 DAPF improved growth traits, fruit coloration, fruit yield and quality attributes. All applied concentrations of WSCN reduced russeting in Gale Gala apple significantly. The effects of the integrated fertilizers schedules with WSCN on russet control were also evaluated. EMLA.111 was the most suitable clonal rootstock, where, the rate of russeting on fruits was less compared to EMLA.7 irrespective of the WSCN treatments tested. The phenological observations in relation to the initiation of the flowering lasting for 19 days were also recorded. The pest management programme was adopted to manage the apple pest complex. Between the different schedules with foliar WSCN, the differences were also recorded in amount of russeting on EMLA.111/ EMLA.7 rootstocks compared to control. The schedules with foliar WSCN on a wet canopy noticed less russetted fruits. The study also identified the relationship between yield and productivity traits using path coefficient analysis to know the direct and indirect effects of independent variables on managerial ability of the crop. Principle component analysis (PCA) of fruit quality traits was also worked out for differences among WSCN formulations tested which accounted 100% of the cumulative variance.

Key words: Dry temperate, Foliar spray, Gale Gale apple, Plant and soil attributes, Russeting

Apple (*Malus* × *domestica* Borkh.) is the most important cash crop of Himachal Pradesh, the hill State of India, constitutes about 49% of the total area under cultivation and 85% of the total fruit production, thereby, generating an economy of around 523 million US dollars. The Kinnaur, a tribal district stretching up to the Tibetan border in southeast (altitude: 2320-6816 m amsl) represents the dry temperate region in north-west Himalaya. Apple farming on 86% of total fruits area resulting into 99% of total fruits production by the farmers of this district has tremendously resulted in amelioration and transforming the economy of the tribal district in a big way. The growers primarily use NPK mineral fertilizers and farmyard manure (FYM) as traditional orchard fertilization in late autumn to early spring (Kumar *et al.* 2017). However, the increasing fertilizer cost and its scarce availability to meet out the real fruit crop demands for specific nutrients to hill people indicated low productivity (69.5 q/ha) of the orchards. Further, the nutrients mining from the soil on continuous basis coupled with imbalanced use of fertilizers has resulted in increasing deficiencies of secondary and micronutrients which is limiting crop response to NPK.

The alternative solution to crop fertilization, the customized fertilizers (CFs) which are multi-nutrient carriers designed for foliar and/ or soil application, contain macronutrients (NPK), meso-nutrients (Ca, Mg) and micronutrient cations (Fe, Cu, Zn, Mn), both from inorganic and/or organic sources, satisfying the crop nutritional needs, specific to its site, soil and stage and validated by a scientific crop model. The CFs are unique, readily and completely water soluble in nature, formulated on sound scientific plant nutrition principles, and evaluated through field research (Rakshit *et al.* 2012). The 'Central Fertilizer Committee' has included CFs in the Fertilizer (Control) Order, 1985, as a new category of fertilizers that are soil

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and crop specific. In the need of the hour, foliar application of WSCN has been proved beneficial as the foliar feeding is a relatively new technique of feeding plants by applying liquid fertilizer directly to their leaves (Kumar *et al.* 2017). Moreover, apple cultivars differ in their susceptibility to russeting in early stages of fruit development than those of later stages (Knoche *et al.* 2011). The russeting on the skin of apple fruits is the result of an interaction between epidermal structure which was more or less sensitive to disturbances occurring in fruits, caused by a variety of environmental factors namely high relative humidity, rainfall fluctuations, low temperature during night and use of agrochemicals. Knoche *et al.* (2011) further confirmed the period of maximum sensitivity to russeting occurrence between the second and fourth weeks after flowering, when the fruit diameter is between 15 to 30 mm. In order to have the optimum utilization of plant nutrients with minimum environmental pollution, it is desirable and necessitates the fruit orchardists to the environment safe and appropriate use of foliar nutrition fruit production. Therefore, the aim of this work was to optimize the dose of foliar nutritive feeding of WSCN on vegetative growth traits and nutrient dynamics of Gale Gala apple under dry temperate ecosystem. It is also of importance to record flowering behaviour, fruit set, yield and quality characteristics at various stage specific WSCN application in sandy edaphic conditions in the dry temperate region.

MATERIALS AND METHODS

The experiment was conducted at RHRTS and Farm Science Centre (KVK) of Dr Y S Parmar University of Horticulture and Forestry, Sharbo (Reckong Peo), Kinnaur, Himachal Pradesh, India (31°32’20” N and 78°16’03” E) during two consecutive harvest seasons (2013 and 2014). The experimental area was typically a dry temperate region (annual rainfall between 350-400 mm) and the average temperature remains as low as -4ºC in January and February months. The valley area included the trans-Himalayan belt on the northern side of the western Himalayas, which is cold, arid and windswept (Kooppen’s climate classification).

The Gale Gala apple orchard was established in 2008 on trees grafted onto virus-free dwarfing rootstock clones, viz. EMLA.111 and EMLA.7. The feathered plants procured from ‘Van Well’ fruit nursery, USA, were planted with the graft union 15 cm above the soil line in north-south row orientation, spaced at 2.5 m × 2.5 m within and between rows. The pollinizer cultivars, Gibson Golden (grafted onto EMLA.111/EMLA.7) and Golden Spur (grafted onto EMLA.111) were maintained as complete separate line of trees within the experimental orchard. The phenological observations in relation to the initiation of flowering, and the full flowering in main and pollinizer trees were also carried out. The flowering period of the pollinizer trees coincided fully with that of the main cultivars and lasted for 19 days.

The experiment was laid out on gravely sandy loam textured soil with coarse sand (41.3%), fine sand (49.9%), silt (29.2%), clay (19.2%), CEC (6.3 C mol (P+)/kg), bulk density (1.30 g/m), water holding capacity (31.5%), pH 7.10, electrical conductivity (0.15 d S/m), SOC (4.04 g/kg), available N (309.8 kg/ha), $NaHCO_3$-extractable P (11.7 kg/ha), K (342.8 kg/ha), and DTPA extractable micronutrients cations (mg/kg) viz. Zn (1.97), Mn (45.8), Fe (57.3) and Cu (2.52). The trees also adopted all the usual horticultural practices in accordance with the scientific principles, the framework of fertilization, weed control and other optimal plant protection operations (Table 1).

The tree fertilization of NPK soil fertilizers at four levels, viz. 100, 80, 60 and 40% of recommended dose of fertilizers (RDF) were supplemented along with WSCN foliar formulation namely, K_2O:S:Mg:Ca:Zn:B in 6:11:5:0.3:0.3:0.4, w/w elemental ratio in various conjoint combinations. The treatment schedule (fertilizer factors) followed is depicted in Table 2. The experiment was arranged as RCBD with three replicates, and three trees per rootstock clone per treatment for each harvest season. RDF-NPK (70:35:70 one-year old tree^{-1} basis) was applied as calcium ammonium nitrate (CAN, 25% N), single super phosphate (SSP, 16% P_2O_5) and muriate of potash (MOP, 60% K_2O). During the experimentation, one third dose of N, the full of P and K fertilizers, and FYM were supplemented as band application in January. The remaining two-third dose of the N was applied in April at 45 cm away from the tree trunk. The ‘multiplex’ a micronutrient formulation containing Mn (1%), Fe (2%), Zn (3%), Cu (0.5%) and B (0.5%), expressed as v/v was sprayed twice at 0.25% during the petal fall and the grand growth stage of the trees. Besides, the fertilization management schedule was also followed as foliar boric acid (1%, w/w) at pink bud stage, and $CaCl_2$ (1%, w/w) at fruit set to peanut stage (20 mm fruit diameter), and also at walnut to 80-90% of mature fruit size stage.

The soil difference within the orchards were monitored and assessed. The baseline soil samples, each weighed up to 1

Table 1 Plant protection operations adopted for Gale Gala apple in dry temperate regions

Month	Chemical applied	Number of applications	Rate (%)	Target
April- May	Tree spray oil + chlorpyrifos	1	2 + 0.2	San Jose scale, mite eggs, blossom thrips
May- June	carbedazim + mancozeb	1	0.5 + 2.5	Pre mature leaf fall, powdery mildew, core rot
June- July	carbedazim+ mancozeb, fenazaquin	1, 1	0.5 +2.5, 0.025	Pre mature leaf fall; mite infestation
July- August	dimethoate, zineb + propergite	1,1	0.2, 3.0 + 0.57	Woolly aphid; Pre mature leaf fall, mite infestation
August- Sept	fenazaquin	1	0.025	Mite infestation
Nov- December	chlorpyrifos + copper oxychloride	1	0.2 + 0.5	San Jose scale, woolly aphid infestation, Canker

Source: Kumar and Chandel (2017)

Table 2 Factor levels of fertilizers

Fertilizer factor	Fertilization level*				Fertilizer treatment (T)	Rate		WSCN Spray version and schedule (g/tree)		
	100%	80%	60%	40%				15 DAPF	30 DAPF	45 DAPF
N	560	446	336	224	T_1	100% NPK	(+)	$WSCN_{100}$ + $urea_{25}$	$WSCN_{100}$	$WSCN_{100}$
P	280	224	168	112	T_2	80% NPK	(+)	$WSCN_{100}$ + $urea_{25}$	No spray	$WSCN_{100}$
K	560	446	336	224	T_3	60% NPK	(+)	$WSCN_{75}$ + $urea_{25}$	$WSCN_{75}$	$WSCN_{75}$
WSCN (w/w, foliar)	K_2O:S:Mg:Ca:Zn:B (6:11:5:0.3:0.3:0.4)				T_4	40% NPK	(+)	$WSCN_{75}$ + $urea_{25}$	No spray	$WSCN_{75}$
Mode of N supply	1/3 of dose in January, 2/3 of dose in April				T_5 (Control)	RDF-NPK	(+)	Water spray only		

WSCN, Water soluble customized nutrients; DAPF, days after petal fall; *100% Soil fertilization for 8-year age group (g/tree) basis as RDF; $WSCN_{100}$, 100 g/tree WSCN; $WSCN_{75}$, 75 g/tree WSCN; $urea_{25}$, 25 g/tree urea

kg were collected using an auger of 10 cm diameter at 15-30 cm depth of the surface soil in the rhizosphere of common vetch. Soil characteristics of apple orchards were analyzed based on texture characteristics including WHC (Keen-Raczkowski Box method; Piper 1966) and bulk density (Kanwar and Chopra 1976). The chemical properties of soils were determined according to standard methods. Soil pH and EC were measured in 1:2.5 soil-water suspensions. Soil OC was analyzed according to Walkey and Black (1934), available N by alkaline potassium permanganate method (Subbiah and Asija 1956), P (0.5 M $NaHCO_3$ extractable) by Olsen *et al.* (1954) and 1N neutral ammonium acetate extractable and K was estimated by flame photometry (Merwin and Peach 1951). Meso-nutrients (exchangeable Ca, Mg) were determined according to ammonium acetate method (Black 1957). DTPA extractable Fe, Cu, Zn and Mn, was buffered at pH 7.3±0.05 according to Lindsay and Norvell (1978), and analyzed using Atomic Absorption Spectrophotometer model-4141.

Agro-morphometric growth traits of apple trees were recorded and the means were compared using standard errors of the mean. To measure the tree height from the lowest scaffold branch, the distance between graft union to end of the highest branch in main trunk was recorded in centimeter (cm). The representative sample of uniform and healthy one-year-old spur bearing shoots were selected randomly from all the four directions (east, west, north and south) to measure the annual shoot extension growth at the end of growing season (October month) and expressed in centimeter (cm). Spur length, spur thickness, length of flowering shoot, and the tree trunk circumference (at 15 cm above the graft union) were measured using a digital caliper, and then used to calculate the trunk cross-sectional area (TCSA, cm^2) by using formula (TCSA=$girth^2/4\pi$) as described by Kumar *et al.* (2008). Canopy volume (CV) was calculated by assuming central leader and slender spindle tree represented by cylinders capped with cones, with height of the cone equal to the radius of the cylinder. The distance below the bottom branch to the soil was not included in the volume calculation, assuming the shape of a cone and was estimated using formula (πr^2 x h)/3, where, r=radius and h=plant height, in which radius (r) mean from all the directions of crown was measured. The representative sample size of 50 fully expanded and matured leaves from all over the tree canopy were taken and the cumulative area was recorded with leaf area meter and expressed in square centimeter (cm^2).

The flowering period on each experimental tree at full bloom in the last week of April to the first week of May, using full-tree blossom cluster count was also recorded. The clusters of bloom were marked to record the number of fruits developed from the specific cluster of flowers. The fruit set was performed approximately four weeks after the end of blooming, when natural June fruitlets drop was completed. Fruit set was determined as the percentage of fruits to total remaining flowers and, therefore, is an expression of flower quality, according to the formula, fruit set (%) = (number of fruitlets after June drop per cluster/number of flowers in cluster at full bloom) × 100. Similarly, fruit drop (%) at 20 days after petal fall was calculated using the formula, fruit drop (%) = (Total number of fruitlets- number of fruitlets)/ Total number of fruitlets) × 100.

Fruit yield (kg/tree) was recorded in each commercial harvest, from 2013 through 2014. Within each year, a mean of three harvests were recorded, and for each season, the cumulative yield was determined. The trunk circumference and leaf area in each treatment were used to work out the yield efficiency (YE calculated as a ratio of yield kg/cm of TCSA, yield kg/m of CV, yield kg/m of CA and kg/m of LA) according to Westwood (1978). The number of root suckers ($tree^{-1}$) was also recorded and were subsequently removed after counting. Fruits harvested at physiological maturity stage based on fruit firmness, size and typical variety colour during September to mid of October, were thereafter, utilized for analyzing pomological traits. The variables, viz. fruit dimensions were measured as the length and width of fruit samples with a digital caliper; fruit fresh weight (g) using an electronic balance; fruit firmness using Effegi Penetrometer and total soluble solids content (TSS) at 25±2°C at consumer maturity with a hand refractometer (°Brix) was determined. Fruit juice pH was measured after dilution of the juice at 1:20 ratio with distilled water. Titratable acidity (TA) was determined by neutralization reaction in the diluted juice solution by titrating to pH 8.2 using 0.1 N NaOH, expressed as % (w/v) malic acid, then TSS:TA ratio was calculated. Sugars (reducing sugars, non-reducing sugars and total sugars) and ascorbic acid contents were determined according to AOAC (1980).

The colour of every apple fruit in various conjoint foliar WSCN treatments was also recorded. The colour rating of the epidermal surface area was evaluated visually with a red-orange blush by estimating the sum of the percentage of the skin surface with 'good' red colour plus one-half the per cent of the skin surface with 'compensating' red colour.

For foliar analysis, the leaf samples were taken at 120 DFFBH from the middle part of the one-year old shoots all around the periphery of the tree. The samples were collected between the mid July and August (middle of the current season's growth) from the middle pair of leaflets. The represented sample size of 100 pairs of leaflets from the randomly selected trees was tested. Sampling and the chemical analysis was carried out according to Chapman (1964). The digestion of leaf sample (1 g) for the estimation of total N was carried out in concentrated H_2SO_4, contained a digestion mixture of potassium sulphate (400 parts), $CuSO_4$ (20 parts) and selenium powder (1 part). For the estimation of P, K and B, the samples (0.5 g) were digested in diacid mixture (HNO_4:$HClO_4$) in the ratio of 4:1 (Piper 1966). Total leaf N was determined using a nitrogen auto-analyzer. P estimated by the phosphovanadomolybdate method (Jackson 1973). K concentration was determined by Atomic Emission Spectroscopy, whereas, micronutrients were quantified on Atomic Absorption Spectroscopy.

Deviation from optimum percentage (DOP) indexing is capable of accurately defining the quantity and quality of each nutrient in plants: optimum (DOP=0), deficiency (DOP<0) or excess (DOP>0) was computed (Montañés *et al.* 1991). The absolute value of DOP index indicates the significance or severity of an anomalous nutritional status. A large absolute value in DOP indicates a large deviation from the optimum situation. For any given element, a negative DOP index indicates the deficiency, whereas, a positive DOP index indicates an excess. The DOP index based on leaf analysis is calculated using general formula, DOP= $\{C_n/C_o-1\} \times 100$, where, C_n= foliar concentration of the tested nutrient, and C_o= critical optimum (reference) nutrient concentration. The C_0 was taken from optimum values, proposed by Bergmann and Neubert (1976) for apple. Besides, it provides the general nutritional status of nutrients through ΣDOP index, and obtained by adding the values of DOP index irrespective of the sign. Larger the ΣDOP value, the greater is the intensity of imbalances among nutrients and the lower the ΣDOP value, the greater is the intensity of balance among nutrients.

Statistical analyses were carried out using general linear model. The mean values for the respective parameter were the differences between the means of different treatments. These values were compared by the least significant difference (LSD) tested at probability value p=0.05, wherever, the results were significant, therefore, a separate analysis of variance was conducted on each harvest period. For multiple comparisons, Duncan Multiple Range Test (DMRT) at P=0.05 was carried out according to DSAASTAT version 1.514 (Onofri 2007). Furthermore, to have a deeper insight into, the direct and indirect effects of yield components (independent variables) on dependent variable, the path coefficient analysis was carried out as per the method suggested by Dewey and Lu (1959). The correlation between all possible combinations including leaf nutrient content, TCV, CA and fruit yield influenced at WSCN formulation was worked out according to Prasad and Rao (1989). The data reduction using the principle component analysis (PCA) of all possible traits for total harvest periods was calculated according to XLSTAT version 2015.6.01 (Addinsoft USA).

RESULTS AND DISCUSSION

Morphometric growth traits

The morphometric growth traits were significantly improved under different levels of NPK fertilization + foliar WSCN supplemented. The data depicted in Table 3 on vegetative growth traits of Gale Gala apple at WSCN formulations showed significant differences between and within the respective EMLA rootstock clones. The treatment of fertilizer factors arranged in decreasing order of $T_3>T_2>T_4>T_1>T_5$ with respect to vegetative growth attributes of trees grafted onto EMLA rootstock clone. In EMLA.111, the treatment T_3 (60% RDF-NPK+75g WSCN+25g urea at 15 DAPF followed by 75 g WSCN at 30 and 45 DAPF), significantly increased plant height, tree spread, girth and annual shoot extension growth by 23.4, 17.7, 31.7, and 35.5%, respectively, compared to the control. Similarly, the higher respective values were recorded for T_3 in EMLA.7, and the least in T_5 for these traits. The data also showed a relative higher increment in growth parameters in EMLA.111 followed by EMLA.7. Kamble and Kathmale (2015) recorded an increase in vegetative growth traits with the addition of NPK through WSCN. This was attributed to more availability of nutrients, especially N, inducing its simulative effect on cell division and cell enlargement that in turn increased the leaf number and dimensions. Al-Abdulsalam and Hamaiel (2004) observed an increase in plant efficiency for utilization of N, and thus enhanced plant growth traits, after K application. In another test conducted under B deficient environment by Wojcik (2006), Jafarpour and Poursakhi (2011), post-harvest foliar B application improved the generative growth and yield of apples. Nasreen *et al.* (2007) reported that the addition of N and S fertilizers exerted significant influence on morphometric growth characteristics in onion crop. Similar findings have also been recorded by and Kumar *et al.* (2017) in standard and spur apples. Further, the conjoint application of soil NPK fertilization and WSCN revealed a significant increment in leaf area in the cultivar, grafted onto EMLA rootstocks. Conjoint treatment (T_3) attained the highest values of leaf area (49.8, 47.3 cm^2) compared to control with RDF along with water spray in EMLA.111 and EMLA.7 during two successive harvesting seasons, respectively.

Canopy parameters, flower and fruiting behavior

TCSA, TCV and CA measurements were correlated

Table 3 Morphometric traits of Gale Gala apple grafted onto EMLA rootstock clones at WSCN formulations

Rootstock clone	Fertilizer treatment (T)	Plant height (cm)	Tree spread (cm)		TG (cm)	ASEG (cm)	Leaf area (cm^2)	Scaffold branches		Canopy parameters		
			E-W	N-S				Primary	Secondary	TCSA (cm^2)	TCV (m^3)	CA (cm^2)
EMLA.111	T_1	310.7	189.4	147.4	31.6	36.3	47.7	3	3	79.5	82.3	8.9
	T_2	345.3	177.6	144.7	32.7	32.5	46.7	2	2	85.1	98.0	8.2
	T_3	364.7	209.6	187.9	39.4	44.4	49.8	6	5	123.6	150.3	12.4
	T_4	320.8	198.7	151.8	29.5	34.7	45.9	3	2	69.3	74.1	9.6
	T_5	279.3	179.5	147.5	26.9	28.6	43.4	3	2	57.6	53.6	8.4
	Mean	324.2	191.0	155.9	32.0	35.3	46.7	3.4	2.8	83.0	91.7	9.5
	CV (%)	8.5	5.7	9.4	12.6	14.4	2.3	35.6	39.7	15.7	21.1	10.8
	LSD (p=0.05)	49.3	19.6	26.1	7.2	9.0	1.9	2.1	1.9	23.3	34.3	1.8
EMLA.7	T_1	272.0	150.8	144.4	28.3	34.5	46.1	3	3	63.8	57.8	6.8
	T_2	283.7	149.3	140.3	25.2	31.8	45.2	3	3	50.6	47.8	6.6
	T_3	293.3	167.7	177.6	36.5	41. 7	47.3	2	2	106.1	103.7	9.4
	T_4	265.3	157.3	152.8	29.2	30.9	45.8	3	3	67.9	60.0	7.5
	T_5	251.7	142.1	137.2	21.4	26.4	42.6	2	2	36.5	30.6	6.1
	Mean	273.2	153.4	150.5	28.1	30.9	45.4	2.6	2.6	64.9	59.9	7.3
	CV (%)	2.9	3.9	6.4	12.1	8.8	2.9	13.4	13.4	24.1	26.1	10.5
	LSD (p=0.05)	14.4	10.7	17.2	6.1	5.2	2.4	0.6	0.6	27.7	27.8	1.4

EMLA, East Malling Long Aston; E-W, east-west; N-S, north-south; TG, tree girth; ASEG, annual shoot extension growth; TCSA, trunk cross-sectional area; TCV, tree canopy volume; CA, canopy area

through 2013 until 2014 for growth dynamic of canopy parameters at EMLA.111/EMLA.7 rootstock clones. TCV and CA for EMLA.111 raised trees increased gradually with the increase of TCSA. The treatment T_3 recorded the highest value for TCV (150.3 m^2) and CA (12.4 cm^2) with TCSA (123.6 cm^2), whereas, the lowest mean values in T_5 were observed with a statistical significant difference (Fig 1). The data on flower and fruiting behavior of apple during 2013 through 2014 vegetation period showed that apple trees grown on EMLA.111 exhibited greater number of leaves per flowering shoot with maximum TCSA than those on EMLA.7 in T_3 conjoint WSCN formulation. Among different WSCN formulation tested on different rootstock clones, the tree flowering attributes were markedly influenced by both cultivar and rootstock. The beginning of respective bloom date on shoots was generally accrued on April 3 and April 17 for EMLA.111 and April 4 and April 17 for EMLA.7 rootstock clones under T_3 treatment combination. Further, 75% of bloom was recorded earlier on EMLA.111 rootstocks. The results have also allowed establishing that treatment T_3 had a positive influence on growth of the flowering shoot, under both of the rootstock clones tested. In 'Gale Gala' apple trees, flowering attributes irrespective of rootstock clone were markedly influenced by conjoint WSCN formulations. The data recorded on the mean length, thickness of flowering shoot, number of flower cluster per flowering shoot and number of flowers per cluster as significantly higher in EMLA.111 raised trees under T_3 than in EMLA.7 rootstock clone.

Spur characteristics, yield-related attributes and root suckering

EMLA.111 followed by EMLA.7 rootstock clone is the most suitable rootstocks for Gale Gala apple trees grown in sandy soils (Kumar and Chandel 2017). Where, the rate of flower bud burst was faster, full bloom earlier, average number of flowers per branch greater, percentage of fruit set

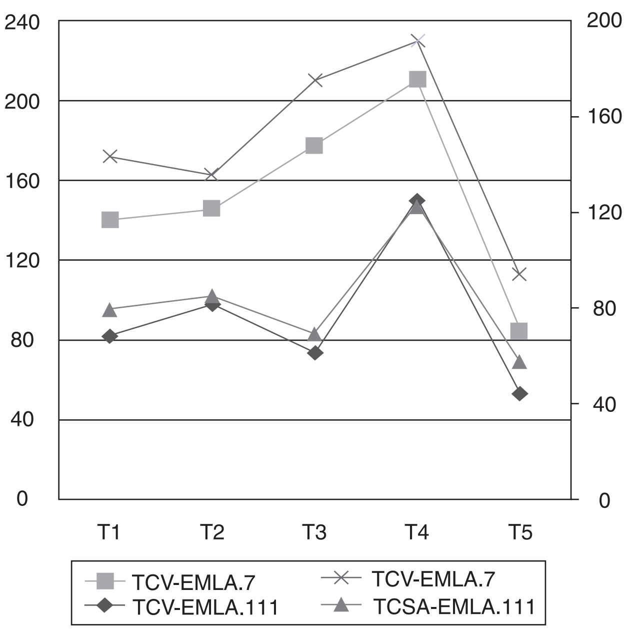

Fig 1 Comparative generation developments of TSCA and TCV in Gale Gala apple on EMLA clonal rootstock.

on one years old spur was higher with increased fruit yield and quality traits. In EMLA.111 clonal rootstock raised Gale Gala apples, maximum spur length and thickness of 49.6 mm and 15.5 mm respectively, was recorded in T_3 treatment compared to T_5. Similarly, the spur development differed significantly between the treatments combinations applied in EMLA.7 clonal rootstock raised trees which had longer and thickened spurs of 48.7 and 12.2 mm, respectively (Table 4). Foliar WSCN fluids have improved fruit set and reduced fruit drop significantly over the control. In the respective rootstock clones tested, maximum fruit set (64.8 and 61.3%) and reduced fruit drop (9.14 and 9.25%), was recorded in T_3 compared to T_5. Foliar application of WSCN in spring along with inorganic NPK ditch application of nutrients causal significant increase of fruit yield in treated trees compared with control ones. The present study revealed a profound significant yield differences after application of foliar WSCN formulations in combinations with reduced soil fertilization at different EMLA rootstock clones tested. T_3 produced maximum yield at 41.7 kg/tree in Gale Gala (EMLA.111) trees, whereas, the minimum yield (29.4 kg tree^{-1}) was obtained in T_5, which was statistically similar to T_2 and T_4 produced 39.1 and 36.2 kg fruit tree^{-1}, respectively. Similarly, fruit yield in EMLA. 7 raised trees was recorded in the order of $T_3 > T_2 > T_4 > T_1 > T_5$. It is evident from the data that highest cumulative fruit yield recorded under T_3 was higher than control in EMLA.111 (29.6%) and EMLA.7 (34.5%). In addition, Amiri *et al.* (2008) and Kumar *et al.* (2017) claimed that foliar nutrients were more efficient than soil fertilization. However, they also recommended a combination of both methods to manage nutrition of trees such that the highest yield and heaviest fruit was obtained through combined treatment of Zn and N through foliar application and soil manuring. These studies correspond with our research results. Sotiropoulos *et al.* (2008), Sharma *et al.* (2011) and Kumar *et al.* (2017) recorded that application of N increased fruit yield of apple. In the present study, the combination of T_3 enhanced the efficiency of other nutrients as compared to single nutrient application, while over supply of N caused lodging, and lower quality (Beuerlein *et al.* 1992). Therefore, in appropriate combination of 60% RDF-NPK+75g WSCN+25g urea nutrient application recorded the maximum yield and production. Concerning YEs, expressed as Y/TCSA, Y/TCV, Y/CA, Y/LA recorded at various WSCN formulations is presented in Fig. 2 A-B. The best YE for EMLA.111 rootstock raised trees was recorded in T_3 followed by T_1, T_3 and T_4. The YE (Y/CV) recorded the highest in T_2 followed by T_1 and T_3. Similar trend was also recorded in EMLA.7 raised trees. The data depicted on the number of root suckers as 2-5 with EMLA.111, and 2-6 with EMLA.7 rootstocks under various WSCN formulations applied. Smaller, but still abundant root suckers were noticed in T_3 on EMLA.111, and EMLA. 7 rootstock clones.

Fruit quality

The fruit physical-biochemical traits of 'Gale Gala' apple trees in studied variants went through some changes compared to control either on EMLA.111 or EMLA.7. Indeed, it is suggested that 60% RDF-NPK and WSCN fluids, had justified better response on these traits. Gale Gala

Table 4 Spur characters, fruit yield-related attributes, yield and root suckering (Σ2013-14) of Gale Gala apple influenced by various WSCN formulations.

Rootstock clone	Fertilizer treatment (T)	Spur length (mm)	Spur thickness (mm)	Fruit set (%)	Fruit drop (%)	Yield (kg/tree)			Cumulative yield (kg/tree)	Root suckers/ tree
						2013	2014	Mean		
EMLA.111	T_1	36.7	10.7	49.6^{c}	9.81^{ab}	33.6	36.2	34.9	69.8	4
	T_2	35.2	10.3	44.5^{d}	9.69^{b}	37.7	40.5	39.1	78.2	3
	T_3	49.6	15.5	64.8^{a}	9.14^{c}	39.7	43.7	41.7	83.4	2
	T_4	34.9	11.4	58.4^{b}	9.84^{ab}	34.5	37.8	36.2	72.3	4
	T_5	25.4	9.2	36.1^{e}	9.87^{a}	29.4	29.3	29.4	58.7	5
	Mean	36.4	11.4			34.9	37.5	36.3	72.5	3.6
	CV (%)	20.4	18.2			6.5	8.3	7.4	7.4	17.3
	LSD (p=0.05)	13.3	3.7			4.1	5.5	4.8	9.5	1.1
EMLA.7	T_1	35.9	10.9	44.1^{c}	9.34^{b}	29.2	32.6	30.9	61.8	3
	T_2	41.2	11.1	40.4^{d}	9.39^{b}	32.4	36.7	34.6	69.1	4
	T_3	48.7	12.2	61.3^{a}	9.25^{b}	36.3	39.5	37.9	75.8	2
	T_4	35.6	8.9	53.4^{b}	9.31^{b}	28.9	31.3	30.1	60.2	2
	T_5	22.1	8.6	35.7^{e}	9.72^{a}	22.4	27.2	24.8	49.6	6
	Mean	36.7	10.3			29.8	33.5	31.7	63.3	3.4
	CV (%)	13.9	6.7			8.9	7.5	8.1	8.1	35.3
	LSD (p=0.05)	9.1	1.2			4.8	4.5	4.6	9.1	2.1

Mean followed by same letter within columns are not significant according to DMRT (P=0.05)

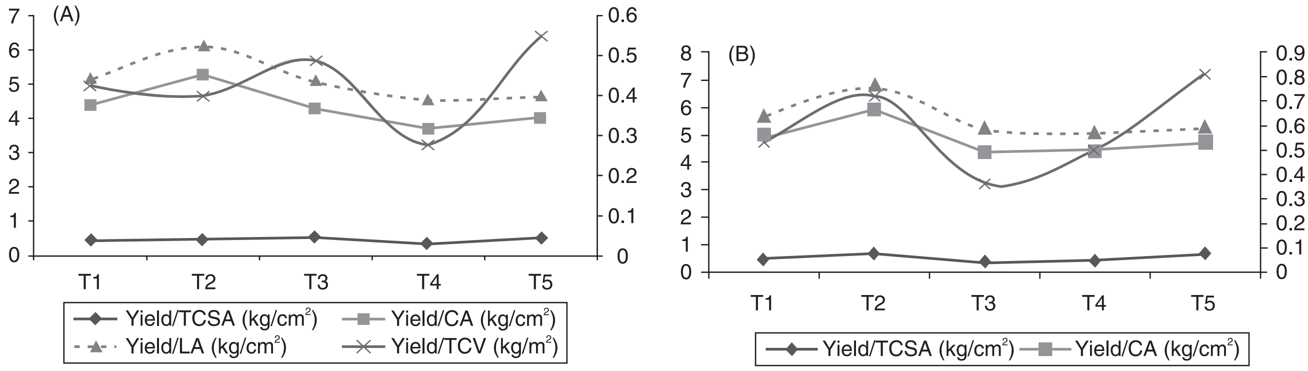

Fig 2 Yield efficiency for Gale Gala apple onto EMLA.111 (A) and EMLA.7 (B) clonal rootstocks.

(EMLA.111) apple exhibited maximum fruit length (69.3 mm), width (85.7 mm), weight (186.2 g), volume (196 cc) and firmness (6.5 kg/cm^2) in T_3 with corresponding values of 59.8 mm, 79.6 mm, 181.7 g, 179.7 cc and 6.37 kg/cm^2, respectively, in EMLA.7 raised apple trees. The data also indicated that fruits on EMLA.111 rootstock clone showed less fruit juice pH, higher TSS and TSS: TA ratio than those on EMLA.7 rootstock trees. The content soluble solid is a feature of the variety/ rootstock clone and after its value, it can establish the optimal harvest time. As closer to harvest time, the intensity of accumulation of soluble dry substances decreases (Pesteanu 2015). Concerning to the fruit sugar content (reducing, non-reducing and total sugars), the results showed that Gale Gala (EMLA.111) revealed highly significant values compared to EMLA.7 rootstock tested for WSCN formulations. Itoo and Manivannan (2004), and Bhatt and Srivastava (2005) recorded increased TSS, fruit firmness and titrable acidity due to treatment combinations of reduced NPK and water foliar applications in tomato. The present results are in close conformity with the findings of Shivakumar *et al.* (2000) who supplemented organic manures along with varied inorganic fertilizers for the betterment of yield and total sugar contents. Applied conjoint applications with WSCN were effective on fruit qualitative specifications such as TSS and TSS: TA, which were found to increase. Conformity of reduced fruit tissue firmness indicates a superior quality of fruits in this treatment compared with control. Drake *et al.* (2002) obtained the best treatment for improved quality of apple fruit through low amounts of nitrogen application. Similarly, total ascorbic acid content in fruit trees grafted onto EMLA.111 was significantly higher compared to EMLA.7 in WSCN formulations applied. The increase in ascorbic acid content might be due to adequate supply of NPK nutrients to the plants through varied levels of WSCN fertilizers. While, the fruit colouration at 4-point (Red) scale was not significantly affected by integrated WSCN formulation in either on EMLA.111 or EMLA.7, but revealed largest values on EMLA.111 in T_3. It is evident from the present study that EMLA.111 was the most suitable rootstock grown in sandy soils, where, rate of russeting on fruits was less compared to EMLA.7, irrespective of the WSCN treatments tested. It was also observed that 'Gale Gala' fruits onto EMLA rootstock clones presented different degrees of susceptibility to russeting and were more susceptible in early stages of development than those in later stages. Only the dosage and schedules with WSCN (T_3) on a wet canopy recorded very less russeted fruits compared with the worst case in T_5 grafted either onto EMLA.111 or EMLA.7 rootstock clones. The fruit quality as a result of N fertilizer as urea application indicated negative effect of nitrogenous fertilizer on fruit colour, texture firmness and TSS level of apple (Nava *et al.* 2008).

DOP indexing

In the present study, the foliar WSCN fertilization had a significant effect on the amount of leaf macro-, meso- (Ca, Mg) and micronutrient (Fe, Cu, Zn, Mn) concentrations of EMLA.111/EMLA.7 trees. Small but non-significant differences among various WSCN formulations used were observed for leaf N, P, K, Ca, Mg and micronutrient concentrations. In Gale Gala/EMLA.111 apples, the treatment T_3 resulted in maximum leaf N content (2.72%) followed by T_2, T_4 and T_1 compared to the control with corresponding treatments T_3, T_4, and T_1 in EMLA.7. This superior combination with WSCN also resulted into maximum leaf P (0.236%) in T_3, which was statistically at par to T_2, T_1 and T_4, recording 0.226, 0.206 and 0.196%, respectively. Similarly, leaf K, Ca, Mg, Fe, Cu, Zn and Mn were also influenced significantly by foliar WSCN applied in similar trend, in Gale Gala, irrespective of rootstock clones tested.

The data showed a relative deviation to the optimum of foliar macronutrient contents in all conjoint foliar WSCN fertilizer treatments (Table 5). In general, the $DOP_{N, P, K, Mg, Fe, Cu, Zn, Mn}$ was positive and DOP_{Ca} was negative in Gale Gala (EMLA.111) apples regardless of WSCN fertilization (T_3). In EMLA.7 rootstock grafted trees, the $DOP_{Ca, Fe}$ level in the trees fertilized with T_3 tended to have a negative DOP value. The results inferred that leaf N, P, K, Mg, Cu and Zn was in optimum and or excessive range, when leaf Ca was in deficiency and has also been reported by Nachtigall and Dechen (2006) and Kumar *et al.* (2017). The negative DOP_{Ca} attributed to its low mobility and low availability in soil, while, negative $DOP_{Fe, Zn, Mn}$ in some WSCN conjoint treatment combinations

Table 5 The DOP index and ΣDOP determined from apple leaf nutrients at WSCN formulations in Gale Gala apple at 120 DFFBH

Rootstock clone	Fertilizer treatment (T)	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn	ΣDOP
EMLA.111	T_1	+33	+106	+123.3	-14	+16	-4.2	+7.5	+4	+4	312[d]
	T_2	+35	+126	+128.3	-12	+16	-8.8	+18	+3	+13.5	360.6[b]
	T_3	+36	+136	+140	-11.5	+36	4.5	+33.5	+16	+31	444.5[a]
	T_4	+33	+96	+115	-18	+24	-10.7	+11.5	+8.7	+19	335.9[c]
	T_5	+31.5	+86	+113.3	-19	+12	-11.7	+3	-1	+3	278.5[e]
	Mean										346.3[A]
EMLA.7	T_1	+29.5	+96	+121.7	-16.5	+8	-8.7	-6.5	-14.7	-8	309.6[c]
	T_2	+28.5	+76	+113.3	-17	+20	-11.8	+2.5	-4.3	+3.5	276.9[d]
	T_3	+34	+116	+133.3	-14.5	+24	-4.5	+11	+4.3	+15.5	357.1[a]
	T_4	+30	+96	+125	-19.5	+12	-11.2	+9	-1.3	+9.5	313.5[b]
	T_5	+25.5	+67	+110	-17.5	+8	-14.7	-13	-25.3	-12	293[d]
	Mean										310.1[B]

Leaf composition standards for apple based on mid-shoot leaves sampled (Bergmann and Neubert 1976); sign (−) indicates deficiency level, sign (+) indicates excessive level according to Montañés *et al.* (1991); DFFBH, days from full bloom to harvest; mean followed by same small and capital letters within columns indicate significant differences among ΣDOP indexes within each fertilizer treatment and the rootstock clone are not significant according to DMRT (P=0.05).

indicated the tendency of these nutrients deficiency under all fertilizer treatments, although its soil contents were optimum. Saykhul *et al.* (2014) ascertained the reason and explained it by their decreased availability in the soil due to fixation by clay particles. Becerril-Román *et al.* (2004), Neilsen *et al.* (2004) and Kumar *et al.* (2017) recorded that soil fertilization of N, P, K, Mg improved leaf N, P, K, Mg contents, ascribed to low soil water and high air temperature resulted limited nutrients uptake, and also limited the organic matter decomposition in sandy soils. The data showed the highly significant differences for nutritional balance (ΣDOP) between WSCN treatments within and between EMLA.111/EMLA.7 clonal rootstocks studied. The negative (deficiency), excessive (optimum) and larger the ΣDOP levels, the greater was the intensity of imbalances among nutrients according to Montañés *et al.* (1991, 1993). Earlier studies are well-documented which did not find any significant differences for balances for leaf nutrient contents (Jimenez *et al.* 2004, Kumar *et al.* 2017, Zarrouk *et al.* 2005). Gale Gala (EMLA.111) exhibited better balanced leaf nutrient concentration compared to Gale Gala (EMLA.7) at various WSCN fluids application, which confirmed the better adaptation of EMLA.111 rootstock clone to slightly acidic and sandy soils associated with higher tree vigour than EMLA.7 rootstock clone.

Path coefficient analysis for leaf nutrient effects, tree volume and canopy area on fruit yield

This study determined the correlations and path analysis of yield and yield related components to evaluate soil fertilization and WSCN combinations' suitability in successful and viable apple crop management in dry temperate region (Table 6). The path coefficient analysis has been used successfully to clarify interrelation between yield and several other characteristics for fruit crops (Majumder *et al.* 2012, Kumar *et al.* 2015). The information generated by correlation analysis confirmed the degree of relationship so as to have detailed information on the direct and indirect effects of various variables. Fruit yield was taken as dependent variable on various leaf nutrient concentrations, tree canopy volume and canopy area. In EMLA.111 trees, the path analysis revealed that leaf K (1.1511) and leaf Mn (1.6422) also recorded the high magnitude of direct effect towards fruit yield indicating the true and perfect relationship between them. This study was in accordance with those of Kumar *et al.* (2015) who suggested the application of these nutrients as highly rewarding for improving the fruit yield of mango and apple (Kumar *et al.* 2006). However, the direct and indirect effects whether positive or negative with respect to leaf N, Fe, Cu, Zn, TCV and CA were negligible. Similarly, in EMLA.7 grafted trees, leaf Fe (-1.3074) and leaf Cu (-3.2031) exhibited a strong negative direct effect on fruit yield, whereas, it was positive with leaf Mn (4.0619) and TCV (3.1926). A positive or negative direct effect via leaf P (-0.1712) followed by leaf Ca (0.4257) on fruit yield was also noticed. However, all other effects whether positive or negative carried a little significance. The residual value of 0.7208 (EMLA.111) and -2.3733 (EMLA.7) indicated the collective influence of the variables on fruit yield and was to the respective magnitude of 0.2792 and -1.3733.

Path coefficient analysis for leaf nutrient effects, tree volume and canopy area on fruit russeting

In EMLA.111 grafted trees, leaf Fe (1.3304), leaf Cu (2.6876) and CA (1.1394) exhibited a strong positive direct leaf nutrient effect on fruit russeting. However, a negative

Table 6 Path analysis showing direct and indirect effects of leaf nutrient concentrations, tree canopy volume and canopy area on fruit russeting of 'Gale Gala' apple grafted onto EMLA.111 rootstock clones at WSCN formulations

Leaf nutrient	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn	TCV	CA	Fruit yield	Correlation matrix with fruit russeting
N	0.000	0.000	-2.0940	0.000	-2.2185	0.9115	2.5070	0.000	0.3719	0.000	0.7036	-0.9238	-0.3933
P	0.000	0.000	-1.2547	0.000	-1.4949	1.2233	1.2724	0.000	0.1362	0.000	0.5547	-0.1165	0.4704
K	0.000	0.000	-2.4884	0.000	-1.8668	0.8431	2.4733	0.000	0.3155	0.000	0.7997	-0.9506	-0.4910
Ca	0.000	0.000	-2.2777	0.000	-0.7426	0.5240	1.9186	0.000	0.1740	0.000	0.4149	-0.8107	-0.4173
Mg	0.000	0.000	-1.5064	0.000	-3.0838	1.0485	2.2482	0.000	0.4288	0.000	1.0683	-0.7055	-0.3203
Fe	0.000	0.000	-1.5769	0.000	-2.4302	1.3304	1.9011	0.000	0.2860	0.000	0.8824	-0.3979	0.1820
Cu	0.000	0.000	-2.2899	0.000	-2.5796	0.9411	2.6876	0.000	0.4153	0.000	0.9426	-1.0076	-0.5426
Zn	0.000	0.000	-0.4713	0.000	-2.4560	0.8510	1.0610	0.000	0.2691	0.000	0.9394	-0.1554	0.0073
Mn	0.000	0.000	-1.7307	0.000	-2.9145	0.8388	2.4604	0.000	0.4537	0.000	0.9879	-0.9207	-0.5764
TCV	0.000	0.000	-2.4164	0.000	-2.3673	0.9128	2.6264	0.000	0.3812	0.000	0.9483	-0.9934	-0.5490
CA	0.000	0.000	-1.7464	0.000	-2.8913	1.0303	2.2233	0.000	0.3933	0.000	1.1394	-0.7085	-0.3603
Fruit yield	0.000	0.000	-2.1461	0.000	-1.9741	0.4803	2.4571	0.000	0.3790	0.000	0.7324	-1.1022	-0.8168

Residual = -0.6044; diagonal figures are the direct effects; N, nitrogen; P, phosphorous; K, potassium; Ca, calcium; Mg, magnesium; Fe, iron; Cu, copper; Zn, zinc; Mn, manganese; TCV, tree canopy volume; CA, canopy area.

direct effect via leaf K (-2.4884) followed by leaf Mg (-3.0838) on fruit russeting was noticed. While, all other leaf nutrient effects, whether positive or negative have been found carrying little significance (Table 7). The residual value of -0.6044 indicated the collective influence of the variables on fruit russeting and was to the magnitude of 0.2792. It can be inferred that leaf nutrient concentrations, TCV and CA contributed to the extent of 27.9% towards fruit yield and russeting. In EMLA.7, a strong positive direct effect of leaf P (2.8003), leaf Mg (1.6743), leaf Zn (1.5391) and CA (4.8144) on fruit russeting was also recorded, while, all other direct and indirect effects on fruit yield, were very small . In present investigation, the correlation matrix between fruit yield and russeting was measured and discussed. Further, the relationship among different agronomic and morphological characters is an important aspect for better planning of orchard fertilization program and further helpful in determining the components of complex trait like fruit yield (Kumar *et al.* 2015). But the correlation alone cannot prove the exact picture of the relative importance of direct and indirect influences of each of the component characters towards yield. The results of

Table 7 Path analysis showing direct and indirect effects of leaf nutrient concentrations, tree canopy volume and canopy area on fruit russeting of Gale Gala apple grafted onto EMLA.7 rootstock clones at WSCN formulations

Leaf nutrient	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn	TCV	CA	Fruit yield	Correlation matrix with fruit russeting
N	0.000	2.4245	0.000	-3.5452	0.8813	-0.4717	0.000	1.2108	0.1589	-2.3259	3.9338	0.000	-0.0974
P	0.000	2.8003	0.000	-2.9528	0.7973	-0.1553	0.000	0.8162	0.1474	-1.5876	2.4179	0.000	0.0991
K	0.000	1.4516	0.000	-1.0875	0.8155	-0.4692	0.000	1.3563	0.1931	-1.5761	3.2155	0.000	0.1527
Ca	0.000	1.4529	0.000	-5.6914	0.7390	-0.5641	0.000	0.2504	0.0152	-2.7199	3.9983	0.000	-0.7921
Mg	0.000	1.3336	0.000	-2.5120	1.6743	-0.4511	0.000	0.1103	0.2043	-1.6352	2.7074	0.000	-0.2743
Fe	0.000	0.5501	0.000	-4.0613	0.9555	-0.7905	0.000	0.6182	0.0826	-2.6401	4.5103	0.000	-0.6961
Cu	0.000	2.0151	0.000	-0.2791	1.2560	-0.0570	0.000	0.4758	0.2345	-0.5335	1.0303	0.000	0.3777
Zn	0.000	1.4851	0.000	-0.9258	0.1200	-0.3175	0.000	1.5391	0.1137	-1.3176	2.7058	0.000	0.2508
Mn	0.000	1.6425	0.000	-0.3448	1.3611	-0.2597	0.000	0.6964	0.2513	-0.8992	1.8791	0.000	0.2753
TCV	0.000	1.5069	0.000	-5.2471	0.9280	-0.7074	0.000	0.6874	0.0766	-2.9502	4.7241	0.000	-0.6851
CA	0.000	1.4064	0.000	-4.7267	0.9416	-0.7406	0.000	0.8650	0.0981	-2.8948	4.8144	0.000	-0.6011
Fruit yield	0.000	0.8214	0.000	-4.8179	1.2554	-0.6261	0.000	-0.1348	0.0697	-2.4287	3.6610	0.000	-0.8331

Residual = -30.8254; diagonal figures are the direct effects; N, nitrogen; P, phosphorous; K, potassium; Ca, calcium; Mg, magnesium; Fe, iron; Cu, copper; Zn, zinc; Mn, manganese; TCV, tree canopy volume; CA, canopy area.

correlation studies between yield and yield contributing characters revealed the inherent relationship among them. The relationship of leaf nutrient effects, TCV and CA with fruit yield can be explained as physiological trait. In order to find out relationship between fruit yield and quality component especially russeting, the path coefficient study at genetic and phenotypic level is required further. This study allows the partitioning of the correlation matrix between yield and its components into direct and indirect effects.

Principle component analysis

The PCA analysis (data reduction) transformed the data which are mutually correlated into principal components (PCs). PCA evaluated the differences induced within WSCN treatments for fruit quality attributes of Gale Gala (EMLA.111/EMLA.7) apples. The graphical interpretation of correlation biplots and *Scree* plots was done by constructing PCA biplots with the original factors/variables drawn as *Eigen vectors* to summarize the correlation between the variable and both illustrated axes of fruit quality attributes (Table 8). PCA studies indicated that only four first components, which accounted for maximum of the total variance. PCA identified for four factors based on *Eigen value* (>1) and explained 88.7 in first-(PC1), 92.4 in second-(PC2), 97 in third-(PC3) and 100% in fourth-(PC4) of the cumulative variance, respectively. The first (PC1), which accounted for about 88.7% of the variation, was strongly associated with fruit dimensions (length, breadth), fruit weight, volume, firmness, sugar contents, ascorbic acid, colouration and russeting . Furthermore, the factor loadings (+ or – signs) indicated the direction of the relationship between the component and the variables. The selection therefore, can be done according to the PC1 which was helpful for a good fertilization program for improve fruit quality traits. Scree plot showed break point that comes after PC4. So, we have considered PC4 which explained 100% of the cumulative variance. PC4 accounted for the highest total variances among different foliar WSCN combinations applied. The minimum data set suggested for fruit quality attributes by PCA, i.e. highly weighted variables (factor loadings >0.40) among different PCs according to Wander and Bolero (1999), Kumar *et al.* (2016) and Kumar and Chandel (2017) for fruit length, breadth, weight, firmness, juice pH, TSS, TSS: TA, reducing sugars, non-reducing sugars, total sugars, ascorbic acid and fruit colouration. The PCA study has also shown that PCA-F1 had the highest positive loadings from all traits, except acidity and russeting, where, it was negative.

Conclusions

The determination of the effect of WSCN has not been adequately studied previously in dry temperate environment. To our knowledge, the present study has quantified nutrient pools and their contribution to the current season's nutrient demand in mature and field-grown apple trees. EMLA.111 followed by EMLA.7 rootstock clone is the most suitable rootstocks for 'Gale Gala' apple trees being grown in sandy soils, where, the rate of flower bud burst was faster, full bloom earlier, the average number of flowers per branch greater, percentage of fruit set on one years old spur was higher with increased fruit yield and quality traits. Further, the application of 60% RDF-NPK+75 g WSCN+25 g urea at 15 DAPF followed by 75g WSCN at 30 and 45 DAPF recorded a significant increase in qualitative attributes which are the function of nutrient relations. The DOP and ΣDOP indexes showed the balanced nutritional values, irrespective of rootstock clone, thus confirmed the better adaptation with tree vigourness on EMLA rootstock clones in the dry temperate ecosystem.

Table 8 PCA (Pearson, n) and factor loadings in fruit quality attributes at various WSCN formulations in Gale Gala apple grafted onto EMLA rootstock clones

Parameter		*Principal component*			
		PC1	PC2	PC3	PC4
Eigen value		12.1	1.76	0.69	0.45
Variability (%)		80.7	11.7	4.5	2.9
Cumulative variance (%)		80.7	92.4	97.0	100.0
Fruit quality attributes		*Factor loadings*			
		F1	F2	F3	*F4*
Fruit length		0.93	-0.14	-0.34	0.01
Fruit breadth		0.93	0.28	-0.01	-0.22
Fruit weight		0.98	0.15	0.03	0.10
Fruit volume		0.92	0.37	-0.05	0.09
Fruit firmness		0.97	-0.09	0.11	0.21
Juice pH		0.54	-0.70	0.35	0.31
Total soluble solids		0.89	0.05	0.36	-0.28
Acidity		-0.51	0.73	0.39	0.22
TSS: acid ratio		0.83	-0.46	0.25	-0.20
Reducing sugars		0.95	0.32	-0.01	0.03
Non-reducing sugars		0.98	0.17	0.04	0.05
Total sugars		1.00	0.08	-0.01	0.05
Fruit colouration		0.93	-0.25	-0.24	0.12
Ascorbic acid		0.98	0.05	0.09	-0.19
Russeting		-0.96	-0.22	0.16	-0.11
		Factor scores			
Rootstock clone	*Fertilizer treatment (T)*	*F1*	*F2*	*F3*	*F4*
EMLA.111/ EMLA.7	T_1	-0.83^d	1.56^a	-1.26^d	0.33^b
	T_2	1.71^c	-0.06^c	0.88^a	1.08^a
	T_3	1.97^b	1.33^b	0.75^a	-0.91^d
	T_4	3.52^a	-1.95^e	-0.65^c	-0.30^c
	T_5	-6.38^e	-0.88^d	0.27^b	-0.20^c

Mean followed by same letter within columns are not significant according to DMRT (p=0.05); F1, factor-1; F2, factor-2; F3, factor-3; F4, factor-4; PC1, Principal Component-1; PC2, Principal Component-2; PC3, Principal Component-3; PC4, Principal Component-4.

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