channels essentially contain coarse sediments. Especially where the palaeochannels are contiguous with the active channels and where flood water collects in such palaeochannels, the groundwater potential is high. In the case of the Assi palaeochannel, most of the ponds/tanks within the channel do not dry up completely even though other ponds on either side go dry by February–March. Some waters in the ponds within the channel remain even during summer and the same ponds within the channel get replenished earlier than other ponds during the rainy season. Normally ponds have an inlet (from either a small local stream or a big river) and an outlet to remove excess water. Even nowadays during the rainy season, water collects in this palaeo Assi channel strip and to prevent the flooding of fields within this strip, a number of canals are taken out of this palaeo Assi river course. This is the first study of the palaeo course of Assi river presenting visual evidence from satellite data. This is also the first attempt to work out the present course and catchment of Assi through high resolution (1 m cell) digital elevation model and field mapping.

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Influence of different sources and methods of potassium application on the quality of grapes cv. Sharad Seedless (*Vitis vinifera* L.)

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Potassium is often considered as the quality element for crop production. Grapevine is one of the most potassium-friendly plants that has a better ability to utilize soil potassium. Grape berries are a strong sink for potassium, particularly during ripening. To ascertain the influence of the combined application of different sources and methods of potassium application on the quality of grape cv. Sharad Seedless, an experiment was conducted at Indian Institute of Horticultural Research, Bengaluru during two consecutive years, viz. 2016–17 and 2017–18 with three different sources of potassium fertilizers (SOP, KNO_3 and 19 : 19 : 19), and two methods of application (soil application and fertigation). Pooled analysis revealed that among the treatments, grapevines treated with sulphate of potash as 60% through fertigation and

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40% through soil registered the highest total soluble solids (22.16° ºBrix), Brix : acid (36.38), total sugars (19.66%) and least titratable acidity (0.61%) in berries. With regards to biochemical constituents like total phenols, total flavonoids and anthocyanins, significantly highest value was observed in vines treated with 100% SOP through fertigation.

Keywords: Fertigation, grape, potassium, source and method, soil application.

GRAPE (*Vitis vinifera* L.) is one of the most important fruit crops having agronomic and economic importance[1]. The average grape yield in southern India ranges from 25 to 35 t/ha, depending on the variety. In terms of its global consumption, a large portion of grapes produced is used for wine and raisin-making, while a small portion is used for table purpose in many grape-growing countries. In contrast, bulk of the production in India is used for table purpose, followed by raisin- and wine-making. It is consumed for its taste with high sugar content in glucose form and gets directly absorbed into the body. Grape is a rich source of minerals like iron, phosphorus and calcium as well as vitamins like B1 and B2.

The fertilization of grapevine is an important practice that affects the production in terms of both quality and quantity[2]. Potassium (K) is among those mineral elements (N, P, and Mg) that continue to accumulate throughout berry growth. It is also known that grapevine is one of the most potassium-friendly plants and has a better ability to utilize soil potassium[3]. Potassium is an important nutrient for grapes not just because it increases yield, but also because it influences metabolic processes like photosynthesis, respiration, translocation of photosynthates, and directly influences the quality of grapes by increasing the sugar content[4]. The aim of the present study was to evaluate the effect of combined application of different sources of potassium (SOP, KNO_3 and 19 : 19 : 19) and their methods of application (direct soil application and fertigation) on the quality of grape cv. Sharad Seedless.

The experiment was conducted for two consecutive years, viz. 2016–17 and 2017–18 in randomized block design (RBD) consisting of eight treatments replicated four times (Table 1) at the ICAR-Indian Institute of Horticultural Research, Bengaluru. Twelve-yr-old grapevines of cv. Sharad Seedless (*Vitis vinifera* L.), grafted on Dogridge rootstock and trained on the 'Y' trellis were utilized in the experiment. Sharad Seedless is one of the highly accepted cultivars in western and southern India in recent years. Berries are black and seedless, with very sweet and crispy pulp. It is a medium-duration variety which requires about 125–130 days for ripening. The spacing followed was 3.0 m × 1.8 m.

'Two pruning and single cropping' system of grape cultivation was followed, as this is the standardized method of grape cultivation for the region. Vines were pruned twice; once after harvesting of the previous year's crop which is popularly known as foundation pruning/back pruning during summer. After this, the vines were encouraged to develop canes with fruitful buds. The second pruning was done on the developed canes to encourage bunch development, which is called forward pruning/fruit pruning during winter[5]. The other cultural operations like irrigation, plant protection sprays, canopy management practices like shoot thinning, shoot positioning, etc. were done according to the recommended practices. Treatments were imposed 75 days later, after both back and forward prunings. Soil application was done once in 15 days and fertigation was done once in three days from 75 days after both back and forward pruning till 120 days. The other nutrient elements were applied according to the recommended dose.

The total soluble solids (TSS) content of the extracted juice was determined using a hand-held temperature-compensated digital refractometer (ERMA, Japan) and acidity was determined by titration method[6]. Ten grams of pulp was mixed with distilled water, squeezed through a muslin cloth and volume was made up to 100 ml. A known volume of the filtrate (10 ml) was titrated against 0.01 N NaOH using phenolphthalein as indicator, endpoint was determined by appearance of pink colour and its persistence for at least a few seconds. Acidity was calculated as percentage of tartaric acid equivalents using tartaric acid standard curve.

$$\text{Acidity (\%)} = \frac{\begin{array}{c}\text{Titre value}\times\text{Standard value (}\mu\text{g)}\times \\ \text{Total volume of extract}\times \\ \text{Correction factor}\end{array}}{\begin{array}{c}\text{Assay volume}\times \\ \text{Weight of the sample (g)}\times 1000\end{array}}\times 100.$$

Total sugars were estimated by spectrophotometric method as suggested by Somogyi[7] and expressed as percentage. Two grams of pulp was taken and the sugars extracted with hot 80% ethanol twice (5 ml each time). Supernatant was collected and volume made up to 50 ml. From this extract, 0.5 ml sample was taken into evaporating

Table 1. Treatment details for sources and methods of potassium application

Notation	Treatment
T_1	100% SOP through soil
T_2	60% SOP through fertigation + 40% SOP through soil
T_3	60% KNO_3 through fertigation + 40% SOP through soil
T_4	60% 19 : 19 : 19 through fertigation + 40% SOP through soil
T_5	40% SOP through fertigation + 60% SOP through soil
T_6	40% KNO_3 through fertigation + 60% SOP through soil
T_7	40 % 19 : 19 : 19 through fertigation + 60% SOP through soil
T_8	100% SOP through fertigation

SOP, Sulphate of potash.

bowls and kept in a water bath at 80°C for evaporation. After completion of evaporation, 10 ml of distilled water was added to the bowls. From this, 5 ml of the sample was taken to which 0.5 ml of 1 N HCl was added and kept overnight. The next day the sample was neutralized by adding 2–3 drops of phenolphthalein indicator and 40% NaOH until it turned pink in colour. The volume was then made up to 10 ml with distilled water. From this, 0.1 ml of aliquots was pipetted out into test tubes and 0.9 ml of distilled water was added. Then 1 ml of alkaline copper tartrate reagent was added to each tube and the tubes were placed in boiling water for 10 min. Next the test tubes were cooled and 1 ml of arsenomolybolic acid reagent was added to all the tubes. The volume was made up to 10 ml in each test tube with distilled water. After 10 min, absorbance of blue colour was read at 620 nm. From the graph drawn, the amount of total sugars present in the sample was calculated.

$$\text{Total sugars (\%)} = \left\{ \frac{\begin{array}{c}OD_{620\ nm} \times \text{Standard value (µg/OD)} \times \\ \text{Total volume} \times \text{Total volume of extract} \times \\ 100\end{array}}{\begin{array}{c}\text{Assay volume} \times \text{Sample taken} \\ \text{for drying} \times \text{Weight of the sample (g)} \times \\ 1000 \times 1000\end{array}} \right\} \times 2.$$

Total phenol content was estimated by spectrophotometric method using Folin–Ciocalteau phenol reagent[8].

About 5 g pulp was incubated in 20 ml of methanol (80%) for 72 h. Then it was homogenized with methanol (80%) in a pestle and mortar 2–3 times. The extracts were pooled and volume made up to 50 ml. About 0.5 ml of the extract was taken in test tubes and 2 ml of Folin–Ciocalteau phenol reagent was added followed by 3.3 ml of distilled water and mixed well. After 2 min, 1 ml of 20% sodium carbonate solution was added and mixed well. The reaction mixture was allowed to stand at room temperature for 30 min and blue colour intensity was read in a spectrophotometer at 700 nm against blank. A standard curve was prepared using gallic acid as standard. Total phenol content was expressed as mg gallic acid/100 g using the following formula

$$\text{Total phenols} = \frac{\begin{array}{c}OD_{700\ nm} \times \text{Standard value (µg/OD)} \times \\ \text{Total volume of extract} \times 100\end{array}}{\text{Assay volume} \times \text{Weight of tissue (g)} \times 1000}.$$

Total flavonoid content was estimated by spectrophotometric method as suggested by Chun *et al.*[9] About 5 g pulp was incubated in 20 ml of methanol (80%) for 72 h. Then it was homogenized with methanol (80%) in a pestle and mortar 2–3 times. The extracts were pooled and volume made up to 50 ml. About 1.0 ml was taken in test tubes and 0.3 ml of 5% $NaNO_2$ was added. After 2 min, 0.3 ml of 10% $AlCl_3$ was added. After another 2 min, 3.4 ml of 4N NaOH was added. The reaction mixture was allowed to stand at room temperature for 10 min. Absorbance was read at 510 nm against blank using a spectrophotometer. A standard curve was prepared using catechin as standard. Total flavonoid content was expressed as mg catechin/100 g using the following formula

$$\text{Total flavonoids} = \frac{\begin{array}{c}\{(OD_{510}/2) \times \text{Standard value (mg/OD)}\} \\ \times \text{Total volume of extract} \times 100\end{array}}{\text{Assay volume} \times \text{Weight of sample (g)}}.$$

Anthocyanin concentration was estimated by spectrophotometric method[10]. One gram peel was homogenized with acidic methanol (HCl : methanol in 1 : 99) and incubated for 72 h. The homogenate was filtered and the residue re-extracted 2–3 times. The extracts were pooled and volume made up to 50 ml. Whenever necessary, the extract was further diluted with acidic methanol. The colour intensity was measured at 540 nm adjusting 100% transmission against acidic methanol. The quantity of anthocyanin in the sample was calculated using cyanidin hydrochloride as standard and expressed as mg/100 g fresh weight using the following formula

$$\text{Anthocyanins (mg/100 g)} = \frac{OD_{540} \times \text{Standard value (µg/1 OD)} \times 50\ \text{ml} \times 100}{\text{Weight of the sample (g)} \times 1000}.$$

The data presented were pooled means of two years, viz. 2016–17 and 2017–18. The significance of specified treatments on yield, quality and biochemical constituents was determined using one-way ANOVA. Duncan's multiple range test (DMRT) was used to differentiate the means at $P = 0.05$. SPSS for Windows version 9.0 and Microsoft Excel 2007 were used for statistical analysis.

There was a significant effect of different sources and methods of potassium application on yield, quality and biochemical characters of berries. Treatment T_6 showed significantly highest yield vine^{-1} (7.00 kg), while treatment T_8 showed the lowest yield vine^{-1} (4.49 kg) (Tables 2 and 3). Treatment T_2 recorded significantly maximum TSS of 22.16° Brix and it was on par with treatment T_8. Lowest value for TSS of 19.53° Brix was observed for treatment T_6 which was on par with treatments T_7 and T_5 with 19.64° Brix and 19.73° Brix respectively.

Treatment T_6 showed maximum titratable acidity of 0.70% and it was on par with treatments T_4 and T_7. The

Table 2. Effect of different sources and methods of potassium application on yield and quality parameters in grapes cv. Sharad Seedless (pooled data over two years, viz. 2016–17 and 2017–18)

Treatment	Yield per plant (kg)	Total soluble solids (°Brix)	Titratable acidity (%)	Brix : acid
T_1	$5.62^{cd} \pm 1.00$	$20.49^{bc} \pm 0.72$	$0.63^{cd} \pm 0.05$	$32.84^{bc} \pm 3.57$
T_2	$5.43^{d} \pm 1.03$	$22.16^{a} \pm 1.51$	$0.61^{d} \pm 0.03$	$36.38^{a} \pm 3.82$
T_3	$6.36^{ab} \pm 0.53$	$19.91^{c} \pm 0.83$	$0.65^{bc} \pm 0.03$	$30.57^{cd} \pm 2.15$
T_4	$6.00^{bcd} \pm 0.78$	$20.16^{bc} \pm 0.58$	$0.67^{ab} \pm 0.02$	$30.05^{d} \pm 0.87$
T_5	$6.23^{bc} \pm 0.49$	$19.73^{c} \pm 0.91$	$0.66^{bc} \pm 0.04$	$30.11^{d} \pm 2.59$
T_6	$7.00^{a} \pm 0.92$	$19.53^{c} \pm 0.88$	$0.70^{a} \pm 0.04$	$28.05^{d} \pm 1.76$
T_7	$6.63^{ab} \pm 0.73$	$19.64^{c} \pm 1.65$	$0.67^{ab} \pm 0.01$	$29.40^{d} \pm 2.38$
T_8	$4.49^{e} \pm 0.83$	$21.15^{ab} \pm 1.12$	$0.62^{cd} \pm 0.03$	$34.05^{ab} \pm 1.98$
S.E.m. ±	0.26	0.39	0.01	0.92
CD 5%	0.74	1.11	0.04	2.61
CV	12.35	5.43	5.41	8.24

Table 3. Effect of different sources and methods of potassium application on biochemical parameters in grapes cv. Sharad Seedless (pooled data over two years, viz. 2016–17 and 2017–18)

Treatment	Total sugars (%)	Total phenols (mg gallic acid equivalents/100g FW)	Total flavonoids (mg catechin equivalents/100 g FW)	Anthocyanins (mg/100 g FW)
T_1	$18.44^{bc} \pm 0.51$	$143.93^{b} \pm 20.84$	$78.90^{b} \pm 8.31$	$1082.38^{ab} \pm 169.65$
T_2	$19.66^{a} \pm 0.76$	$150.44^{b} \pm 33.37$	$78.80^{b} \pm 14.45$	$948.33^{c} \pm 48.82$
T_3	$17.85^{bc} \pm 0.58$	$148.88^{b} \pm 14.50$	$73.82^{bc} \pm 6.49$	$1065.53^{b} \pm 134.17$
T_4	$17.97^{bc} \pm 0.79$	$140.01^{b} \pm 19.47$	$69.18^{c} \pm 8.27$	$1050.67^{b} \pm 68.22$
T_5	$17.73^{bc} \pm 0.70$	$148.86^{b} \pm 27.86$	$71.87^{bc} \pm 10.19$	$1034.31^{b} \pm 118.09$
T_6	$17.53^{c} \pm 1.05$	$146.15^{b} \pm 13.15$	$73.18^{bc} \pm 3.97$	$1105.60^{ab} \pm 142.61$
T_7	$17.81^{b} \pm 0.38$	$148.68^{b} \pm 24.87$	$73.79^{bc} \pm 8.45$	$1072.29^{b} \pm 168.82$
T_8	$18.58^{b} \pm 0.68$	$167.69^{a} \pm 16.62$	$88.64^{a} \pm 7.56$	$1164.20^{a} \pm 142.93$
S.E.m. ±	0.36	4.41	2.65	30.03
CD 5%	1.04	12.56	7.55	85.53
CV	4.01	8.35	9.86	7.97

lowest titratable acidity of 0.61% was recorded for treatment T_2. Highest Brix : acid ratio (36.38) was observed for treatment T_2 and it was on par with treatment T_8. Treatment T_6 showed the lowest value of Brix : acid ratio (28.05). Significantly highest total sugars content of 19.66% was found for treatment T_2; no other treatment was found on par with T_2. The lowest value of total sugars (17.53%) was reported in treatment T_6, which was on par with treatments T_5, T_3, T_4 and T_1.

Regarding biochemical parameters, significantly highest values of total phenols (167.69 mg gallic acid equivalents/100 g FW) and total flavonoids (88.64 mg catechin equivalents/100 g FW) were found in treatment T_8. None of the treatments was on par with T_8. The least values of total phenols (140.01 mg gallic acid equivalents/100 g FW) and total flavonoids (69.18 mg catechin equivalents/100 g FW) were noted for treatment T_4. Treatment T_8 also recorded significantly highest anthocaynins (1164.20 mg/100 g FW), which was on par with treatments T_1 and T_6. Regarding anthocyanins, lowest value (948.33 mg/100 g FW) was noted in treatment T_2.

Grapevines treated with 60% sulphate of potash (SOP) through fertigation + 40% SOP through soil, resulted in significantly highest TSS (°Brix), Brix : acid and total sugars (%), which also recorded least titratable acidity (%) in berries. This might be due to the involvement of potassium in photo-assimilation, translocation of assimilates and conversion of these assimilates into storage products such as sugar, starch, protein and neutralization of physiologically important organic acids[11].

Potassium is involved in phloem loading and unloading of sucrose and amino acids and storage in the form of starch in developing fruits by activating the enzyme starch synthase[12]. The present results are in conformity with those of Al-Moshileh and Al-Rayes[13] who observed increased TSS and decreased acidity with application of 1500 kg ha^{-1} sulphate of potash through fertigation. El-Nasharty *et al.*[14] reported that application of potassium as potassium sulphate through fertigation at 200 g K_2O $vine^{-1}$ yr^{-1}, showed higher TSS (18.3%). Samra *et al.*[15] also found increased TSS/acid ratio with soil application of potassium as sulphate of potash in Thompson Seedless grape. Increased total Brix : acid and total sugars with the soil application of potassium in the form of sulphate of potassium have also been reported in the literature for grapes, apple and strawberry[16–19].

Treatment T_8 registered significantly maximum amount of total phenols, total flavonoids and anthocynins in grape berries. The increase in production of secondary metabolites in the present study might be due to adequate potassium levels which stimulate the activity of phenylalanine ammonia-lyase that is involved in biosynthesis of total phenolics, flavonoids and anthocyanins through the phenol propanoid pathway[20]. The results are in agreement with those of Delgado *et al.*[21], who reported higher concentrations of phenols in grape berries with the application of potassium at 120 g K_2O vine^{-1} as potassium sulphate. Zangeneh and Rasouli[22] also noted increased phenols, anthocyanins and flavonoids in the grape berries with increased potassium application in the form of sulphate of potash.

Balanced and judicious use of potassium fertilizers had a significant impact on the quality of grapes. Adequate potassium application is needed for translocation of sugars to the berries. The experimental results inferred that among the different sources and methods of application, sulphate of potassium applied more through fertigation (60%) and less (40%) through soil was favourable for quality improvement of grapes through increased TSS, Brix : acid and total sugars with least titratable acidity in berries, whereas biochemical constituents of berries were increased when potassium was applied as sulphate of potassium only through fertigation (100%).

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