IRRIGATION AND MULCH SIGNIFICANTLY ENHANCE YIELD BUT NOT QUALITY OF PURPLE PASSION FRUITS

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ABSTRACT

Purple passion fruit (*Passiflora edulis* f. *edulis* Sims.) is an important fruit in the juice industry but its yields can drastically decline under drought stress. The present study evaluated the effects of irrigation and mulch on drought stress amelioration in purple passion fruits. The experiment was set up in a rain shelter in randomized complete block design, replicated four times and repeated once. The study had four irrigation rates (2.5, 5, 10 and 20 L/plant) and three mulches (black plastic film, wheat straw and none). Each treatment had 12 plants in 45cm x 45cm holes spaced at 1.5m x 1.5m and trellised onto posts and wires. A trench lined with plastic film prevented water seepage across treatments. Plants were maintained uniformly until the fifth week when treatments were imposed. Data were recorded up to 56 weeks after planting (WAP) and subjected to analysis of variance using the SAS software. Irrigation significantly increased fruit number at 52 WAP only, and fruit weight at 48, 52 and 56 WAP. The effect of irrigation on cumulative fruit weight (6016 g/plant) for 20 L was significantly ($P<0.05$) greater than the 5052 g/plant for 2.5 L. Black plastic mulch significantly increased fruit number and weight at 43 WAP only. Irrigation and mulch did not significantly ($P>0.05$) affect passion fruit quality traits which were nevertheless within standard magnitudes. Generally, when irrigating with over 5 L, there was no additional benefit of mulching but mulch ameliorated drought stress when deficit irrigation (2.5 L) was applied. Wheat straw and 10 L/plant once per week is generally optimal and should be used in mitigating drought stress to enhance purple passion fruit yields. Irrigation is more effective in enhancing passion fruit yield than mulching and hence it should be given first priority.

Keywords: purple passion fruit, deficit irrigation, mulch, drought stress, total soluble solids.

INTRODUCTION

Passion fruit is an attractive crop for small-scale farmers because it has good local and export markets, can be harvested throughout the year, is easily transported and has a short maturity period (KHDP, 2004). Passion fruit juice is used in drinks, yoghurt, ice-cream and flavours. Passion fruit juice can be boiled into syrups, sauces, gelatin, candy, sherbets, cakes, meringue or chiffon pies, soups or cocktails. The pulp is processed into jelly or blended with pineapple or tomato to make jam (John and Violet, 1979; Morton, 1987). In 100 g of edible portion, there is 75.1 g moisture, 2.2 g protein, 0.7 g fat, 21.2 g carbohydrate, 0.8 g ash, 13 mg calcium, 64 mg phosphorous, 1.6 mg iron, 28 mg sodium, 348 mg potassium, 700 IU vitamin A, 0.13 mg riboflavin, 1.5 mg niacin, and 30 mg ascorbic acid (Tindal, 1969). The seeds yield 23% oil which is similar to sunflower and soybean oils; consequently, it has edible, as well as industrial properties (Seale and Sherman, 1960; Morton, 1987). The seed oil contains 84.1% unsaturated fatty acids and 8.9% saturated fatty acids, consisting of 6.8% palmitic, 1.8% stearic, 0.34% arachidic, 19% oleic, 59.9% linoleic and 5.4% linolenic acids (Morton, 1987). There is a revived interest in the pharmaceutical industry especially in Europe, in the use of the glycoside *passiflorine* as a sedative or tranquilizer. Italian chemists have extracted *passiflorine* from air-dried leaves of *P. edulis*. In Madeira, the juice is used as a digestive stimulant and treatment for gastric cancer (John and Violet, 1979; Morton, 1987).

Passion fruit bears nearly round or ovoid fruits, measuring 4 - 7.5 cm wide, with a tough, smooth, waxy rind ranging in hue from dark-purple with faint, fine white specks, to light-yellow or pumpkin-colour. The rind is 3 mm thick and adheres to a 6-mm layer of white pith. Within is a cavity filled with aromatic mass of double-walled, membranous sacs, containing orange-coloured pulpy juice and about 250 small, hard, dark-brown or black, pitted seeds. The flavour is appealing, musky, guava-like, sub-acid to acid (Morton, 1987).

The purple passion fruit (*Passiflora edulis*) is adapted to the coolest subtropics or to high altitudes in the tropics. It grows and produces well within 650 to 1,300 m asl. *Passiflora edulis* has temperature requirements ranging from 15°C to 28°C. In more tropical areas the plant remains productive all year round (Morton, 1987). Purple passion fruit requires wind protection and well-distributed rainfall. Generally, annual rainfall should be at least 900 mm, but it can range from 1000 to 2500 mm. However, rainfall must be minimal during flowering as pollen wetted by free moisture bursts open and becomes non-functional. Rain also minimizes insect activity and hinders pollination in varieties that require it (Nakasone and Paull, 1998), resulting in poor fruit set, size and yields.

The purple passion fruit vine is shallow-rooted and hence liable to drought stress. During drought, dry soil conditions cause passion fruits to develop poor fruit set, fruit drop and leaf defoliation, which culminate in low yield, poor fruit quality and high economic loss to farmers (Owen, 1971). The period before rains when high temperatures combined with windy conditions prevail lead to high transpiration demand, causing plants to "shut down" (Chemonics, 2002). In addition, grass mulch is difficult to procure in large amounts and breaks down too quickly under hot weather (Chemonics, 2002). In many tropical regions, documented data on total acreage of purple passion fruits under irrigation, recommended irrigation schedule, irrigation rate per growth cycle, and mulch regime for purple passion fruit production does not exist.

MATERIALS AND METHODS

Study site

The study was conducted in a plastic-covered rain shelter located in the Kenyan highlands (2185 m above sea level). The site experiences temperatures, ranging from 9.1^{o}C to 23.1^{o}C and 1012 mm per annum rainfall. The soils at the site were Vintric molic andosols, well-drained, dark to very dark-reddish brown, friable and silt clays with humic tops and 5.7 pH (Jaetzold and Schmidt, 1983).

Experimental design

The experiment was laid out in a randomized complete block design, with four irrigation rates (2.5, 5, 10, and 20 L/plant once per week) and three types of mulches (wheat straw, black plastic film and none). Each treatment had three plants, replicated four times. The experiment was conducted for 56 weeks after planting and repeated once. Plastic mulch was applied 1 month after planting (MAP) to cover each hole, leaving a perforation around each plant for use in irrigating plants with a watering can. Plastic mulch was replaced whenever it got torn. Wheat straw mulch was similarly applied on holes as for plastic mulch. The thickness and span of the wheat straw mulch was 10 cm aboveground by 30 cm from each plant. Wheat straw was topped up regularly whenever it decomposed and started exposing the soil surface.

Experiment establishment and maintenance

Land was prepared by digging, harrowing and hand-pulverizing to a fine tilth. Experimental plots were set up with rows representing blocks (replications). Planting holes, measuring 45 cm x 45 cm, were dug and all soil removed. Planting holes were spaced at 1.5 m x 1.5 m apart (Gachanja and Ochieng, 2004). The top soil used to re-fill the holes was dug outside near the rain shelter to ensure homogeneity. The top soil inside each planting hole was thoroughly mixed with 5 kg poultry manure one month before transplanting passion fruit seedlings.

Seeds were extracted from ripe purple passion fruits obtained from one vine to minimize genetic variation. They were planted in soil under shade and high temperature in a glasshouse. The seedlings were transplanted at the fourth leaf stage into black polythene bags measuring 15 cm diameter by 23 cm depth and filled with loam soil. Top-dressing with 1 g CAN/seedling was done four weeks later. Seedlings were nurtured in the bags until they attained 30-cm height that indicated readiness for transplanting to the research site (Morton, 1987). Soon after transplanting a trellis with a 40 cm cross bar on top of each 2.1 m tall post and two, 14-gauge wires fastened at the ends of the cross bar to run parallel to each other, was constructed to support the passion fruit vines (Nakasone and Paull, 1998). A 45-cm deep trench was dug between main plots and on the perimeter of the rain shelter. The trench was lined with a plastic film to prevent undesirable seepage of irrigation water and rain water into the experimental area.

Seedlings were tipped soon after planting to stimulate branching. Two main shoots selected from close to the base of each seedling were trained upwards on a sisal twine and towards the same direction on the top wires. Leaves and fruit-bearing laterals on the two main shoots on the top wires were left to grow up to 15 cm above the ground. At transplanting, 170 g of 17N:17P:17K fertilizer was applied as a basal fertilizer to each seedling. The same fertilizer was applied as a top-dress at a rate of 100 g and 70 g per vine at the beginning and in the middle of the fruiting period, respectively (Torsten *et al*., 2004). Pruning of spent laterals was done selectively by cutting them back to a newly developing lateral or sub-lateral (Nakasone and Paull, 1998). Weeding was done every week by rouging as soon as weeds emerged from the ground.

Variables measured

Fruit yield and quality attributes were determined bi-weekly and monthly, respectively, starting from the ninth month after planting. Harvesting was done as soon as the fruits reached physiological maturity, indicated by colour change from green to a tinge of purple. All harvested fruits were counted and weighed.

Quality referred to characteristics that made purple passion fruits attractive to eat or suitable for conversion into juice, ice-cream or other products (Teranishe and Barrera–Beritez, 1981). Quality was determined for four months on a bi-weekly basis. Quality was based on fruit diameter, total soluble solids, number of seeds, juice volume, juice weight and fruit weight. Fruit diameter for nine randomly selected ripe fruits per treatment was measured using a veneer caliper. Total soluble solids (TSS) were measured on the nine randomly selected ripe fruits using a hand-held refractometer (Atagon Unicon N-Labequip). Fruit size and TSS were assessed bi-weekly from the 9th to the 12th MAP. Number of seeds was counted per fruit and fruit juice volume was measured using a graduated cylinder.

RESULTS AND DISCUSSIONS

Effect of irrigation on fruit yield

Irrigation significantly ($P<0.05$) affected fruit number at 52 WAP when the 2.5 L had significantly fewer fruits compared to the other irrigation rates (Table-1). This was probably because fewer fruits had been initiated due to the low water supply for the 2.5 L irrigation rate. The higher rates of irrigation had higher number of fruits possibly because the plants were able to sustain development of more flowers up to fruit maturity stage

(Table-1). The lack of a significant difference in cumulative fruit number at 54 WAP for irrigation rates was attributed to the catch-up effect, whereby plants receiving low amount of water adapted and developed as many fruits as the ones that were receiving high amount of water right from the beginning. Alternatively, plants receiving high amount of water did not support the numerous flowers initiated to maturity stage, as evidenced by the plentiful number that also dropped. Plants normally self-thin flowers in order to remain with a number they can support well (Faust, 1989).

Table-1. Effect of irrigation on mature fruit yield (number/plant).

Irrigation (L/plant)	**Time** (weeks after planting)											
	43	**45**	**47**	**48**	**49**	**51**	**52**	**53**	**54**	**54 CFN**	**56**	**56 CFN**
2.5	4.1	7.7	4.6	5.3	19.2	7.5	6.3[b]	6.0	12.3	72.9	127	200
5	3.7	7.5	8.0	7.2	21.7	6.6	10.4[a]	5.8	11.6	82.2	123	205
10	3.8	7.1	6.5	5.3	24.3	6.3	10.3[a]	6.7	12.8	82.4	126	207
20	5.3	9.1	5.8	8.0	28.1	8.3	11.8[a]	7.0	16.3	98.3	130	228
CV (%)	12.6	11.8	13.6	8.0	10.3	8.3	5.9	10.3	6.3	8.8	25.6	16.8
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	2.94	NS	NS	NS	NS	NS

Means followed by the same letter or no letter, within each column are not significantly (NS) different at $P \leq 0.05$, according to Tukey's HSD test. CFN = Cumulative fruit number.

Effect of irrigation on fruit weight per plant was significant (P<0.05) at 48 and 52 WAP (Table-2). The 20 L irrigation rate had consistently higher fruit weight throughout the fruiting season. The other irrigation rates had inconsistent fruit weights. The effect of irrigation was also significant (P<0.05) on cumulative fruit weight at 54 WAP. The cumulative fruit weight at 54 WAP increased with increase in rate of irrigation. However, there was no significant difference in fruit weights between 2.5 L and 5 L, and among 5 L, 10 L and 20 L irrigation rates.

Table-2. Effect of irrigation on mature fruit weight (g/plant).

Irrigation (L/plant)	**Time** (weeks after planting)											
	43	45	47	48	49	51	52	53	54	54 CFW	56	56 CFW
2.5	74	132	115	113[b]	503	174	138[b]	121	280	1674[b]	3378	5052[b]
5	74	153	164	137[ab]	466	155	245[a]	123	270	1810[ab]	3365	5176[ab]
10	74	150	172	117[b]	613	148	222[ab]	145	339	1993[a]	3287	5280[ab]
20	129	199	173	203[a]	749	213	280[a]	155	434	2544[a]	3472	6016[a]
CV (%)	33	25	29	19	10	13	10	8	12	11	24	19
$LSD_{0.05}$	NS	NS	NS	76.9	NS	NS	95.4	NS	NS	784	NS	854

Means followed by the same letter or no letter, within each column are not significantly (NS) different at $P \leq 0.05$, according to Tukey's HSD test. CFW = Cumulative fruit weight

There was no significant (P>0.05) effect of irrigation on number of fruits or weight of fruits harvested at 56 WAP (Tables 1 and 2). Nevertheless, the 2.5 L had slightly more fruits than the 5 L and 10 L irrigation rates, while the 20 L had the highest number of fruits. These results were also attributed to the catch-up and self-thinning effects (Faust, 1989). The 2.5 L irrigation rate had lower fruit weight probably due to reduced dry matter accumulation. Thus, the plants receiving 2.5 L of water were under drought stress, while those receiving 20 L were not, concurring with observations of Isutsa (2006). These results are similar to those of pepper under deficit irrigation that developed few flowers and fruits (Jaimez *et al*., 2000; Dorji *et al*., 2005).

The cumulative weight of fruits was significantly (P<0.05) different at 56 WAP (Table-2). The cumulative weight of fruits for the 2.5 L irrigation rate was the lowest, implying that the weight of individual fruits was lower compared to that of other irrigation rates. The cumulative weight of fruits increased with increase in irrigation rate probably because of the role irrigation water plays in dry matter synthesis and accumulation in fruits. The cumulative weight of fruits for 2.5 L, 5 L and 10 L of water were not significantly different, implying that the water supplied at these three rates promoted fruit growth to the same extent. The cumulative weight of fruits for 2.5 L and 20 L were the only ones that were significantly different. These results implied that the 2.5 L did not provide enough water to support dry matter accumulation in fruits as did the 20 L of water (Isutsa, 2006).

Effect of mulch on fruit yield

The effect of mulch on the number of fruits was significant (P<0.05) only at 43 WAP when black plastic mulch had the greatest fruit number, followed by wheat straw mulch and lastly no mulch (Table-3). At 43 WAP, there was no significant difference in fruit number for black plastic and wheat straw mulches, as well as for wheat straw mulch and no mulch. During the other growth stages, there was no consistency among the mulches since the trend in number of fruits varied throughout the fruiting season. This was probably because fruits matured at different rates and hence the constant variation in number of those harvested.

At 54 WAP, wheat straw had the highest number of cumulative fruits (Table-3). It was followed by black plastic mulch and lastly by no mulch. Mulches are known to increase soil temperature since the sun's energy passes through them and heats the air and soil beneath them (Hu *et al*., 1995). Other reported benefits of mulch include microclimate and texture improvement, conservation of soil moisture and fertility, and control of weeds, pests and diseases (Niu *et al*., 1998). Very little weed growth occurs under dark mulches as they prevent penetration of light or exclude certain wavelengths of light that are needed by weed seedlings to grow (Ossom *et al*., 2001). Hanada (1991) indicated that mulching could have benefits on soils and their environment. Ramakrishna *et al*., (2006) observed that the more favourable soil environment under polythene and straw mulches, especially during the early part of the growing season, increases the number of pods per plant, pod mass, striking pod and stover yields in groundnuts.

Table-3. Effect of mulch on mature fruit (number/plant).

Mulch type	**Time** (weeks after planting)											
	43	**45**	**47**	**48**	**49**	**51**	**52**	**53**	**54**	**54 CFN**	**56**	**56 CFN**
BP	6.94^{a}	8.75	6.38	6.69	24.00	6.50	8.88	6.13	11.8	86.7	131	216
WS	3.13^{ba}	8.81	6.25	6.13	23.56	8.25	9.75	6.38	14.6	87.7	132	218
None	2.56^{b}	5.94	6.00	6.56	22.38	6.75	10.44	6.63	13.4	81.5	118	198
CV (%)	12.6	11.8	13.6	8.0	10.3	8.3	5.9	10.3	6.3	8.8		
$LSD_{0.05}$	4.22	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter or no letter, within each column are not significantly (NS) different at $P\leq0.05$, according to Tukey's HSD test. BP = Black plastic, WS = Wheat straw, CFN = Cumulative fruit number.

Mulch significantly (P<0.05) affected fruit weight only at 43 WAP (Table-4) when black plastic mulch had the greatest fruit weight followed by wheat straw mulch and lastly no mulch. At 43 WAP, there was no significant difference in fruit weight for black plastic and wheat straw mulches, as well as for wheat straw mulch and no mulch. During the other growth stages, there was no consistency among the mulches since the trend in fruit weight varied throughout the fruiting season. This was probably because fruits accumulated dry matter at different rates and hence the constant variation in the weight of those harvested.

According to Halil *et al*., (2001) both black plastic mulch and wheat straw mulch improved the fruit yield and fruit size of stressed treatments. Mulch substantially decreased electrolyte leakage in strawberry fruits. However, mulch enhanced the concentrations of nutrients in leaves and in strawberry fruits. These results clearly indicate that mulch mitigates negative effects of water stress on plant growth and fruit yield in the field, particularly in semi-arid situations.

The effect of mulch was not significant (P>0.05) both on fruit weight and cumulative fruit weight at 54 WAP (Tables 3 and 4). Nevertheless, wheat straw had the highest fruit number (Table-3), while black plastic had the highest cumulative fruit weight (Table-4). Black plastic mulch had the highest cumulative fruit weight possibly because the passion fruit fruits had higher density compared to those of wheat straw and no mulch.

Mulch had no significant (P>0.05) effect on number and weight of fruits harvested at 56 WAP (Tables 3 and 4). Mulch also had no significant (P>0.05) effect on cumulative number of passion fruits and cumulative weight of passion fruits at 56 WAP (Tables 3 and 4). Nevertheless, mulched passion fruit plants had more fruits and higher fruit weights compared to the non-mulched passion fruit plants.

Khalid *et al*., (2005) conducted an experiment in okra and observed straw mulch produce better results, yielding 6.0 t/ ha, compared to 5.6 t/ha for black plastic mulch. Halil *et al*., (2001) observed both black plastic and wheat straw mulches improve fruit yield, fruit size, plant dry matter and leaf area index of strawberries in the water-stressed treatments. Levent and Ankara (2001) found that wheat straw had highest yield of 4.5 kg of tomatoes followed by black polyethylene (3.8 kg) and control (3.8 kg), although the differences were not significant.

Table-4. Effect of mulch on mature fruit weight (g/plant).

	Time (weeks after planting)											
Mulch	**43**	**45**	**47**	**48**	**49**	**51**	**52**	**53**	**54**	**54CFW**	**56**	**56CFW**
BP	162.2[a]	183.4	176.4	153.3	618.0	151.3	189.2	133.1	294.9	2080.4	3413	5493
WS	59.6[ba]	180.4	147.1	130.6	566.9	197.5	238.4	136.5	357.1	2026.1	3502	5528
None	40.8[b]	111.6	144.9	143.7	562.6	168.1	236.2	137.9	341.1	1909.7	3212	5122
CV (%)	33	25	29	19	10	13	10	8	12	11		
$\mathbf{LSD_{0.05}}$	106	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter or no letter, within each column are not significantly (NS) different at $P \leq 0.05$, according to Tukey's HSD test. BP = Black plastic, WS = Wheat straw, CFW = Cumulative fruit weight.

These results clearly indicate that mulching mitigates negative effects of water stress on fruit yield, particularly in water-stressed situations.

Effect of irrigation on fruit quality

Irrigation treatments used in this experiment did not affect fruit quality attributes: namely, total soluble solids (TSS), fruit diameter, pulp weight, pulp volume, number of seeds and single fruit weight (Figure-1). Nevertheless, total soluble solids were highest for 5 L to 20 L irrigation rates, while 2.5 L had the least TSS probably because the 2.5 L of water was inadequate for TSS synthesis (Figure-1). Total soluble solids obtained were similar to the 15% previously reported by Nakasone and Paull (1998). Water stress have been found to increase the levels of soluble sugars (glucose, sucrose and fructose) in treated grape and wheat plants (Ndung'u *et al*., 1997; Sawhney and Singh, 2002), while it reduces the amounts of starch and total sugars.

Fruit diameter did not vary much among the irrigation rates (Figure-1). This was contrary to the expected increase in fruit diameter with increase in irrigation rate. Therefore, it seems some of the excess water was being diverted to promote vegetative growth at the expense of fruit growth. Nevertheless, passion fruits' diameter fell within the 3.5 to 7.0 cm reported by Nakasone and Paull (1998).

Fruit pulp weight and volume increased in direct proportion with fruit weight (Figure-1). The 20 L had the highest pulp weight of 20.8, while the 2.5 L had the lowest pulp weight of 18.9 (Figure-1). This result was attributed to the high amount of water for 20 L irrigation rate being utilised in synthesis of fruit pulp. The fruit weight across irrigation rates was lower than the 36 g/fruit previously reported by Nakasone and Paull (1998). The lower fruit weight was largely attributed to differences in varieties that were used in these two studies. This is valid because the varieties were not the same.

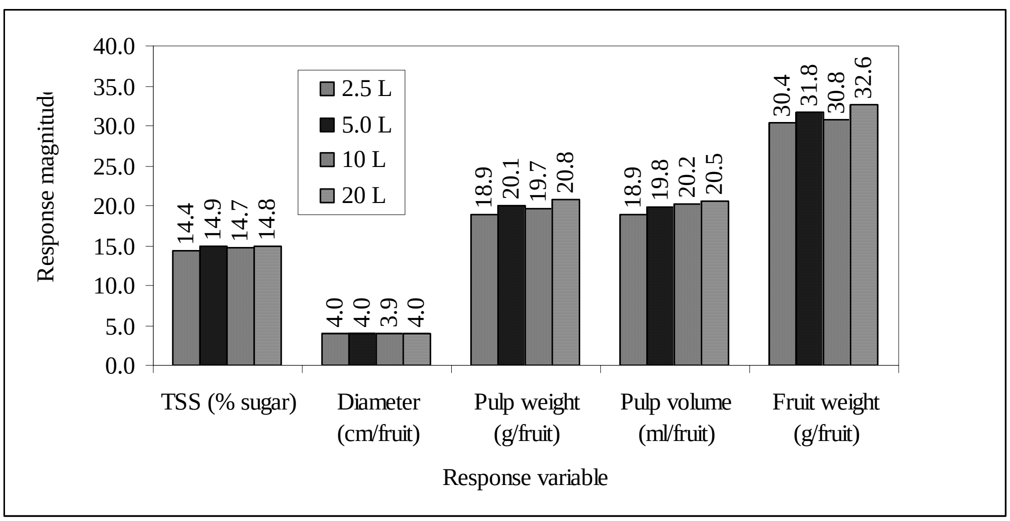

Figure-1. Effect of irrigation on fruit quality attributes.

The number of seeds per fruit increased but not significantly as the rate of irrigation increased (Figure-2). The number of seeds per fruit was: 102 for 2.5 L, 115 for 5 L, 113 for 10 L, and 118 for 20 L. The insignificant increase was probably because irrigation water interacted with other factors such as pollination during seed formation in the purple passion fruits.

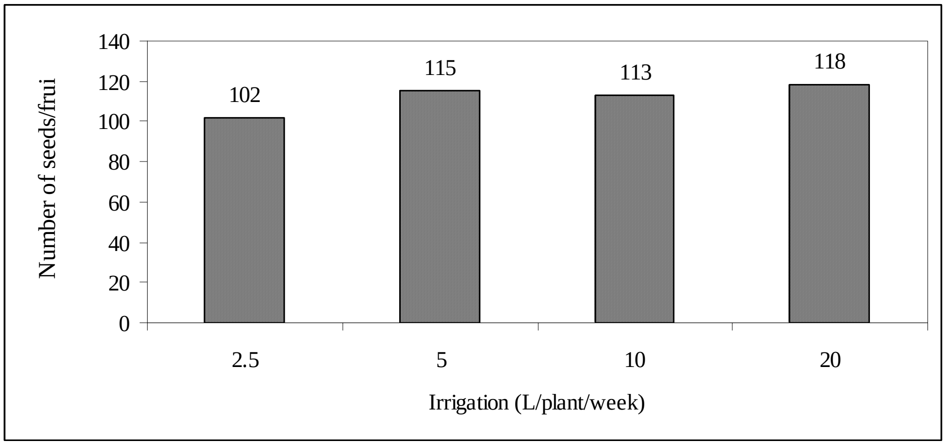

Figure-2. Effect of irrigation on number of seeds per fruit.

Effect of mulch on fruit quality

Mulch had no significant effect (P>0.5) on all fruit quality variables (Table-5). Nevertheless, wheat straw had highest total soluble solids followed by no mulch and lastly black plastic. Wheat straw had the highest pulp weight and pulp volume, suggesting that it was able to conserve more moisture than the black plastic. The number of seeds was higher for wheat straw, compared to black plastic and no mulch. A trend emerged whereby wheat straw was superior to black plastic mulch and no mulch in fruit quality attributes (Table-5). All fruit quality attributes influenced by mulch, except fruit weight, were similar to those previously reported by Nakasone and Paull (1998) in passion fruits.

Table-5. Effect of mulch on fruit quality.

Type of mulch	**TSS**	**Fruit diameter** (cm/fruit)	**Pulp weight** (g/fruit)	**Pulp volume** (ml/fruit)	**Seeds** (No./fruit)	**Fruit weight** (g/fruit)
BP	14.6	3.9	19.2	19.3	108	30.4
WS	14.8	4.0	20.9	21.1	121	32.9
None	14.7	4.0	19.4	19.2	106	30.9
Reported by Nakasone and Paull (1998)	15.0	3.5 to 7.0	-	-	-	36
CV (%)	4.6	4.3	18.6	17.2	22.2	16.7
LSD0.05	NS	NS	NS	NS	NS	NS

Means followed by the same letter or no letter, within a column are not significantly (NS) different at $P \leq 0.05$, according to Tukey's HSD test. BP = Black plastic mulch, WS = Wheat straw mulch

CONCLUSIONS AND RECOMMENDATIONS

Irrigation significantly affects cumulative fruit weight, but does not significantly affect the cumulative number and quality characteristics of passion fruits. Probably water is utilized more in fruit enlargement, development of juice vesicles and fruit pulp after pollination rather than in fruit initiation, explaining the lack of significant difference in number and quality traits of the passion fruits formed.

Although mulch does not significantly affect fruiting, wheat straw promotes the highest number and cumulative weight of passion fruits harvested, while no mulch promotes the least. These results are attributed to the ability of mulch to conserve water used in development of fruits. Similarly, mulch does not significantly affect fruit quality attributes. This result implies that passion fruit quality is not mediated significantly through the mechanisms that mulch uses to influence plant growth and development.

When only 2.5 L of irrigation water is applied to each plant once per week, then it must be combined with mulching to effectively ameliorate drought stress in purple passion fruits. Farmers should use supplemental irrigation of at least 5 L/plant once per week alone or together with wheat straw mulch to ameliorate drought stress, because there is no statistically significant difference between it and the other higher irrigation rates. When 20 L of irrigation water is applied, then mulching should not also be done for the sole purpose of ameliorating drought stress. Mulching can be done under such circumstances only if its other benefits are desired.

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