Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; SP1: 176-180

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(Special Issue- 1)
2nd International Conference
"Food Security, Nutrition and Sustainable Agriculture - Emerging Technologies"
(February 14-16, 2019)

Water productivity in Santa Rosa plum orchard under different water regime and nitrogenous fertilization

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Abstract
With growing water shortages, agriculture faces the challenge of increasing water productivity (WP). In this work, WP of Santa Rosa Plum is evaluated under different irrigation regime practices. WP in Santa Rosa Plum, was estimated over 2 years for two nitrogenous fertilization (N1 -75% additional N and N2 -50% additional N) and three deficit irrigation strategies (I1 -20% SMD of field capacity, I2 -40% SMD of field capacity, I3 -60% SMD of field capacity). In terms of yield/total water supply, the (I1 -20% SMD of field capacity subjected to N1 treatment, gave the highest WP (3.64 kg m-3), compared to the I2 treatment (3.30 kg m-3) and N2 treatment (3.41 kg(m-3). I3 irrigation reduced slightly the performance and yield of Santa Rosa Plum (3.28 kg m-3). Performances of yield were affected by irrigation and nitrogenous fertilization. Interaction between (I1 -20% SMD of field capacity) and (N1 -75% additional N induced better WP.
Experimental work targeted WP under contrasted environments. In northern part of India (125-130 cm annual rainfall), average yield of plum, planted at 6×6 m spacing varied between 12.24 to 16.04 respectively when irrigation was applied under I1, I2 and I3 treatment respectively. The highest WP values were obtained from I1N1, interaction 4.12 kg m-3 respectively and the lowest (3.28 kg m-3 and 3.41 kg m-3) in I3 and N2 treatment. However different interactions with irrigation regime and nitrogenous fertilization are discussed on this paper.

Keywords: Plum trees, prunus salicina, nitrogen fertilization, irrigation, fruit yield, water productivity

1. Introduction
Among the stone fruits, '*Santa Rosa*' plum (*Prunus. salicina*) is one of the important fruit crop of the temperate regions. Efficient orchard management practices have a key role in enhancing the productivity of plums.
Work on the standardization of plum and fertilizer requirement of plum have been conducted separately by several workers under different set of agro-climatic conditions, but virtually no work has been carried out to standardize the optimum levels of water productivity, under different irrigation & N-fertilization of *Santa Rosa* plum. Keeping these facts in view, the present studies were undertaken.
Water productivity has been given different definitions by different authors, often according to the scale of the plant, plot of land or watershed they were investigating or the purpose of their study. Molden (2000) [10] defined water productivity as the physical mass of production or the economic value of production measured against gross inflow, net inflow, depleted water, process depleted water, or available water. Water productivity is usually estimated as the amount of agricultural output produced per unit of water consumed. In its broadest sense it reflects the objectives of producing more food, income, livelihoods, and ecological benefits at less social and environmental cost per unit of water used, where water use means either water delivered to a use or depleted by a use. Put simply, it means growing more food or gaining more benefits with less water. Physical water productivity is defined as the ratio of the mass of agricultural output to the amount of water used, and economic productivity is defined as the value derived per unit of water used. Water productivity is also sometimes measured specifically for crops (crop water productivity). To feed a growing and wealthier population

with more diversified diets will require more water for agriculture on an average annual basis.

2. Materials and Methods

The present studies were undertaken in the experimental orchard of Department of pomology, Dr. Y. S. Parmar University of Horticulture and Forestry, Solan (H.P) during 2010-2012. Seventy two trees of *Santa Rosa* plum with equal age and vigour, spaced at 6 m x 6 m were selected for trial purpose. The experiments was laid out in split-split plot design with, irrigation levels as the main plot, pruning levels as the Sub-plots and nitrogen levels as the Sub-Sub-plot treatment. The experimental unit consisted of a single tree. Yield was recorded as the total fruit weight harvested from the tree in each year and expressed as kg/tree. The pooled analysis (over years) was done and the observation was recorded. Water productivity (WP) was determined as the total Yield per unit of water used. This index was calculated for fresh yield.

3. Results and Discussion

The data pertaining to the effect of irrigation, pruning and N fertilization on the fruit yield are presented in Tables 1 to 3. Application of different levels of irrigation, pruning and nitrogen fertilization significantly influenced the fruit yield, during both the years. Pooled data showed that highest yield of 16.04 kg tree^{-1} was obtained in trees irrigated at 20 per cent soil moisture depletion of field capacity which was followed by 40 per cent soil moisture depletion of field capacity. However, the lowest fruit yield (12.24 kg tree^{-1}) was recorded in I_3 treatment. Irrigation levels values differed from each other during both the years of study.

Pruning treatment had significant impact on fruit yield. The pooled data revealed that highest yield (26.19 kg tree^{-1}) was observed in T_3 treatment closely followed by T_4 treatment recording 24.11 kg tree^{-1}. However, the lowest fruit yield (0.50 kg tree^{-1}) was recorded in T_1 treatments. In nitrogen fertilization treatment higher yield was observed with N_1 treatment (14.84 kg tree^{1}) as compared to N_2 treatment (13.77 kg tree^{-1}).

Interaction effect of irrigation and pruning (IxT) indicated that significantly higher yield (28.93 kg tree^{-1}) was obtained with I_1T_3 interaction which was followed by I_1T_4 and I_2T_3. The lowest yield was recorded in I_3T_1 interaction (0.32 kg tree^{-1}). The interactions between irrigation and nitrogen fertilization were found to be significant for pooled analysis. Highest fruit yield (16.52 kg tree^{-1}) was obtained from I_1N_1 which was followed by I_1N_2 (15.56 kg tree^{-1}) and the lowest fruit yield (11.42 kg tree^{-1}) was recorded in I_3N_2. The pooled value of fruit yield varied between 11.42 kg tree^{-1} to 16.52 kg tree^{-1}.

The interaction effect of pruning and nitrogen fertilization (TxN) significantly influenced fruit yield during both the years of study. Highest fruit yield (27.10 kg tree^{-1}) was obtained from T_3N_1 which was followed by T_3N_2 (25.27 kg tree^{-1}) and the lowest fruit yield (0.45 kg tree^{-1}) was recorded in T_1N_2. Among three factors interaction (IxTxN) the highest yield (30.12 kg tree^{-1}) was obtained with $T_3N_1T_1$ treatment and followed by $T_3N_2T_1$ (27.74 kg tree^{-1}) treatment. The lowest yield (0.23 kg tree$^{-1)}$ was recorded in $T_1N_2I_3$ interaction (Table 3).

Table 1: Effect of different levels of irrigation, pruning and nitrogen on fruit yield (kg tree^{-1})

Treatments	Fruit yield (kg tree^{-1})		
	2010-11	2011-12	Pooled
Irrigation levels (Main Plot Treatment)			
I_1 (20% SMD of field capacity)	7.75 (2.70)	24.33 (4.39)	16.04 (3.54)
I_2 (40% SMD of field capacity)	7.05 (2.58)	22.20 (4.16)	14.63 (3.35)
I_3 (60% SMD of field capacity)	6.44 (2.48)	18.03 (3.69)	12.24 (3.02)
$CD_{0.05}$	0.05	0.10	0.06
Pruning (Sub plot treatment)			
T_1 (Heading back of scaffolds 75%)	0.00 (1.00)	1.01 (0.99)	0.50 (0.69)
T_2 (Heading back of scaffolds 50%)	3.00 (1.98)	9.81 (3.11)	6.41 (2.51)
T_3 (Heading back of scaffolds 25%)	13.14 (3.75)	39.24 (6.25)	26.19 (5.11)
T_4 (Normal Pruning)	12.20 (3.63)	36.02 (5.98)	24.11 (4.90)
$CD_{0.05}$	0.05	0.06	0.03
Nitrogen (Sub-sub plot treatment)			
N_1 (75% additional N as CAN)	7.27 (2.62)	22.39 (4.18)	14.84 (3.38)
N_2 (50% additional N as CAN)	6.88 (2.56)	20.65 (3.98)	13.77 (3.23)
$CD_{0.05}$	0.05	0.03	0.02

Table 2: Effect of different interaction I x T, I x N and T x N on fruit yield (kg tree^{-1})

Interactions	2010-11	2011-12	Pooled
I_1T_1	0.00 (1.00)	1.38 (1.17)	0.69 (0.83)
I_1T_2	3.89 (2.20)	12.13 (3.48)	8.01 (2.82)
I_1T_3	13.95 (3.86)	43.91 (6.62)	28.93 (5.37)
I_1T_4	13.16 (3.76)	39.90 (6.31)	26.53 (5.15)
I_2T_1	0.00 (1.00)	1.08 (1.00)	0.50 (0.70)
I_2T_2	2.80 (1.94)	10.22 (3.19)	6.51 (2.55)
I_2T_3	13.08 (3.75)	39.70 (6.30)	26.39 (5.13)
I_2T_4	12.34 (3.65)	37.86 (6.15)	25.10 (5.01)
I_3T_1	0.00 (1.00)	0.64 (0.79)	0.32 (5.59)
I_3T_2	2.30 (1.81)	7.10 (2.65)	4.70 (2.16)
I_3T_3	12.38 (3.65)	34.10 (5.83)	23.24 (4.81)
I_3T_4	11.09 (3.47)	30.29 (5.49)	20.69 (4.54)
$CD_{0.05}$	0.11	0.11	0.05
I_1N_1	8.03 (2.75)	25.01 (4.46)	16.52 (3.60)

I_1N_2	7.47 (2.66)	23.65 (4.33)	15.56 (3.48)
I_2N_1	7.11 (2.59)	22.74 (4.22)	14.93 (3.39)
I_2N_2	6.99 (2.57)	21.66 (4.10)	14.33 (3.31)
I_3N_1	6.68 (2.52)	19.43 (3.87)	13.06 (3.14)
I_3N_2	6.20 (2.44)	16.64 (3.51)	11.42 (2.89)
$CD_{0.05}$	NS	0.05	0.03
T_1N_1	0.00 (1.00)	1.11 (1.05)	0.55 (0.74)
T_1N_2	0.00 (1.00)	0.90 (0.92)	0.45 (0.65)
T_2N_1	3.19 (2.03)	10.51 (3.23)	6.85 (2.60)
T_2N_2	2.80 (1.94)	9.12 (2.99)	5.96 (2.42)
T_3N_1	13.51 (3.80)	40.70 (6.37)	27.10 (5.20)
T_3N_2	12.76 (3.70)	37.78 (6.13)	25.27 (5.02)
T_4N_1	12.41 (3.66)	37.25 (6.09)	24.83 (4.97)
T_4N_2	11.99 (3.60)	34.79 (5.88)	23.39 (4.82)
$CD_{0.05}$	NS	0.05	0.05

Figures in parentheses are square root transformed values

Table 3: Effect of irrigation, pruning intensities and nitrogen fertilization (I x T x N) interaction on fruit yield (kg tree^{-1})

Interactions	2010	2011	Pooled
$T_1N_1I_1$	0.00 (1.00)	1.46 (1.20)	0.73 (0.85)
$T_2N_1I_1$	4.20 (2.27)	12.51 (3.53)	8.35 (2.88)
$T_3N_1I_1$	14.59 (3.94)	45.66 (6.75)	30.12 (5.48)
$T_4N_1I_1$	13.34 (3.78)	40.43 (6.35)	26.89 (5.18)
$T_1N_2I_1$	0.00 (1.00)	1.30 (1.14)	0.65 (0.80)
$T_2N_2I_1$	3.58 (2.13)	11.76 (3.42)	7.67 (2.76)
$T_3N_2I_1$	13.32 (3.78)	42.16 (6.49)	27.74 (5.26)
$T_4N_2I_1$	12.98 (3.73)	39.38 (6.27)	26.18 (5.11)
$T_1N_1I_2$	0.00 (1.00)	1.07 (1.03)	0.53 (0.73)
$T_2N_1I_2$	2.90 (1.97)	10.76 (3.28)	6.83 (2.61)
$T_3N_1I_2$	13.12 (3.75)	40.86 (6.39)	26.99 (5.19)
$T_4N_1I_2$	12.45 (3.66)	38.25 (6.18)	25.35 (5.03)
$T_1N_2I_2$	0.00 (1.00)	0.94 (0.97)	0.47 (0.68)
$T_2N_2I_2$	2.71 (1.92)	9.68 (3.11)	6.19 (2.48)
$T_3N_2I_2$	13.03 (3.74)	38.54 (6.20)	25.78 (5.07)
T_4N_2I2	12.23 (3.63)	37.48 (6.12)	24.86 (4.98)
$T_1N_1I_3$	0.00 (11.86)	0.82 (0.90)	0.41 (0.64)
$T_2N_1I_3$	2.48 (3.71)	8.27 (2.87)	25.38 (2.31)
$T_3N_1I_3$	12.82 (3.52)	35.57 (5.96)	24.19 (4.91)
$T_4N_1I_3$	11.43 (3.52)	33.07 (5.75)	22.25 (4.71)
$T_1N_2I_3$	0.00 (1.00)	0.46 (0.67)	0.23 (0.47)
$T_2N_2I_3$	2.12 (1.75)	5.94 (2.43)	4.03 (2.00)
$T_3N_2I_3$	11.93 (3.59)	32.64 (5.71)	22.28 (4.72)
$T_4N_2I_3$	10.75 (3.42)	27.50 (5.24)	19.13 (4.37)
$CD_{0.05}$	NS	0.05	0.08

Figures in parentheses are square root transformed values

The data on the effect of orchard management practices on water productivity are presented in (Table 4). Irrigation and nitrogen fertilization had a marked influence on water productivity during both the years. It is evident from the data that trees irrigated at 20 per cent soil moisture depletion of field capacity registered the maximum water productivity (4.01 kg/m^3). The minimum water productivity (3.28 kg/m^3) was recorded under 60 per cent soil moisture depletion of field capacity irrigation treatment. In nitrogen fertilization treatment the highest water productivity (3.64 kg/m^3) was observed in N_1 treatment as compared to N_2 treatment recording 3.41 kg/m^3

Table 4: Effect of different levels of irrigation, pruning intensities and different doses of nitrogen on water productivity (Kg/m^3)

Treatments	Water productivity (Kg/m^3)		
	2010-2011	2011-2012	Pooled
Irrigation levels (Main Plot Treatment)			
I_1 (20% SMD of field capacity)	1.96	6.06	4.01
I_2 (40% SMD of field capacity)	1.51	5.10	3.30
I_3 (60% SMD of field capacity)	1.50	5.05	3.28
$CD_{0.05}$	0.33	0.25	0.11
Nitrogen (Sub-sub plot treatment)			
N_1 (75% additional N)	1.66	5.62	3.64
N_2 (50% additional N)	1.65	5.18	3.41
$CD_{0.05}$	NS	0.09	0.10

Table 5: Effect of I x N interactions on water productivity (Kg/m^3) in plum

Interactions	2010-11	2011-12	Pooled
I_1N_1 = (20% SMD of field capacity + 75% additional N)	2.03	6.22	4.12
I_1N_2 = (20% SMD of field capacity + 50% additional N)	1.89	5.89	3.89
I_2N_1 = (40% SMD of field capacity + 75% additional N)	1.52	5.21	3.36
I_2N_2 = (40% SMD of field capacity + 50% additional N)	1.49	4.98	3.24
I_3N_1 =(60% SMD of field capacity + 75% additional N)	1.44	5.44	3.44
I_3N_2 = (60% SMD of field capacity + 50% additional N)	1.57	4.66	3.11
$CD_{0.05}$	NS	0.10	0.12

Perusal of data enumerated in Table 5 revealed that there was non-significant effect of different levels of irrigation and nitrogen fertilization on water productivity during the year 2010-11. Such effects were statistically significant during the year 2011-12. The pooled data of both the years reveal the maximum water productivity (4.12 kg/m^3) in I_1N_1 interaction, while minimum (3.11 kg/m^3) occurred under I_3N_2 interaction.

4. Summary and Conclusion

The yield showed an increasing trend with the increase in soil moisture. Trees irrigated at 20 per cent soil moisture depletion of field capacity gave significantly higher yield as compared to 60 per cent soil moisture depletion of field capacity (Table 1). These results are in line with those of Marangoni *et al*. (1988) [8] and Ruggiero (1991), who obtained highest yields under frequent irrigation. Sharma and Chandel (2005) [15] also obtained highest fruit yield with irrigation at 80 per cent field capacity and lowest in unirrigated trees. Jhobta (1989) and Prazak and Jansta (1993) [12] also recorded lower fruit yield of apple in unirrigated trees.

Different pruning intensities exerted significant effect on fruit yield during both the years (Table2). The highest yield was observed in lightly pruned trees (HB of Scaffolds 25%) and lowest in heavily pruned trees (HB of scaffolds 75%) in both the years. The yield reduction in the medium and heavily pruned trees was due to the removal of higher proportion of the fruiting wood by shoot shortening. Increased yield from the lightly pruned trees was due to retention of more number of fruiting nodes. Similar increase in yield due to light pruning have also been reported by Kanwar and Nijjar (1983) [7], Badiyala and Awasthi (1989) [2] and Singh (1992).

The effect of fertilizer treatments on yield revealed that N_1 treatment gave the highest yield (14.84 kg $tree^{-1}$) and the lowest (13.77 kg $tree^{-1}$) was obtained from N_2 treatment (Table 2). Similarly, increase in yield with increasing levels of N has also been reported in plum (Chohan and Singh, 1976; Sharma, 2003) [3, 14], peach (Janjic, 1979; George and Nissen, 1992; Meheriuk *et al*., 1995; Saenz *et al*. 1997; Singh and Chauhan, 1998; Arora *et al*., 1999) [5, 4, 9, 13, 1] and almond (Joolka and Sharma, 2000a) [6]. Increased yield at the higher dose of nitrogen might be due to formation of more metabolites produced by larger leaves resulting in more intense fruit bud differentiation, flowering and fruit set and ultimately long period for fruits to utilize assimilates (Sink capacity) (Saenz *et al*. 1997) [13]. The higher fruit yield with N is also attributed the greater tree vigour more leaf area and consequently more photosynthetic activity resulting in the synthesis of greater quality of metabolites. Also the larger and heavier fruits at higher levels of N might also have contributed towards higher yield.

5. Water Productivity

Trees irrigated at 20 per cent soil moisture depletion of field capacity registered the maximum water productivity (4.01 kg/m^3) and the minimum (3.28 kg/m^3) was recorded under 60 per cent soil moisture depletion of field capacity irrigation treatment. The pooled data of both the year reveal the maximum water productivity (4.12 kg/m^3) in I_1N_1 interaction, while minimum (3.11 kg/m^3) occurred under I_3N_2 interaction. This is in line with Nortes *et al.* (2010) who reported that water productivity decreased drastically with the reduction of water application. Xavier Domingo Martinez (2010) [16] stated that N application increased N concentration in leaves, fruit load, canopy size and yield and also increased the water productivity.

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