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Physiological Studies of Drip Irrigated Pointed Gourd (*Trichosanthes dioica* Roxb.)

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Abstract: The present study was carried out with different levels of irrigation, fertilizer and mulch to assess the growth habit, physiology aspect of plant and response to fertigation on fruit yield of pointed grourd in a sub-tropical climate. In drip irrigation method, irrigation and fertilizer are applied through drip simultaneously are placed near the active crop root zone unlike furrow irrigation method. With the results, effectiveness of the applied fertilizer and irrigation increases. If mulch is placed at the top of soil, the upward movement of water through capillary is reduced substantially and adequate soil moisture is maintained in root zone. To evaluate the response of these inputs through drip system, the drip irrigation system was selected and different treatments was tested. In pointed gourd irrigations applied at the rate of 100% of Pan Evaporation (PE) at two days interval produced statistically at par fruit yield in comparison to 80% PE. Hence irrigation at 80% PE may be followed as saving of irrigation water and irrigation water use efficiency in this treatment was higher. With regard to combination of irrigation and fertilizer level, fertigation with 75% of recommended dose with 80% PE irrigation schedule produced maximum fruit yield of 5.46 t ha^{-1} and was comparable with fruit yield of 100% of the recommended dose of fertilizer. Thus application of fertilizer through drip in eight equal splits at monthly interval saved 25% fertilizer without any adverse effect on fruit yield. Under lowest level of fertilizer, FUE, NUE and phosphorus/potassium was maximum. However under the highest level of fertilizer, these efficiencies were low. Variation in carbon dioxide exchange rates due to leaf position, photosynthesis, stomata conductance and diurnal changes in male and female plants of pointed gourd (*Trichosanthes dioica* Roxb.) had significant changes. From the present study, it is inferred that fertigation increases fertilizer use efficiency as well as save good amount of irrigation water.

Key words: Fertigation, irrigation water, diurnal, leaf position, photosynthesis, pointed gourd

Introduction

Pointed gourd (*Trichosanthes dioica* Roxb. Cucurbitaceae) is a tropical vegetable crop. It is commonly called "parval". It has its origin in India. The fruit contain 9.0 mg Mg, 2.6 mg Na, 83.0 mg K, 1.1 mg Cu and 17.0 mg S per 100 g edible part (Singh, 1989). The plant is a perennial dioecious and grows as vines that are pencil thickness with green cordate simple leaves. Flowers are tubular and take

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16-19 days from initiation to anthesis for pistillate flowers and 10-14 days for staminate flowers. Stigma remains viable for 14 h and 40-70% flowers set fruit (Singh *et al*., 1989). It is a warm season crop and during winter it becomes dormant and sprouts again in summer. Research work on this crop is very meager. Research works reported are mainly on nutritional requirement of the crop (Singh, 1989), post harvest physiology (Bose, 1984), root knot nematode and other pests (Mahapatra *et al*., 1999), weed management (Chattopadhyay *et al*., 1997), yield enhancement through growth regulators (Basu *et al*.,1999), micro propagation (Mythili and Thomas, 1999) and on cytological and cytomorphological studies (Chattopadhyay and Sharma, 1991).

This crop is planted during winter season (October onwards). In subsequent hot season, this crop requires frequent irrigation and most of the farmers apply irrigation water by flood methods at 6-7 days interval where the evaporation rate is very high (8-9 mm/day). The water use efficiency in this method is very low as most of the applied irrigation water is lost through deep percolation. But in case of drip/trickle method, the applied irrigation water is placed near the active crop root zone and also applied very frequently i.e., daily or alternate day as per the crop ET rate and no moisture stress is developed in the root zone depth (Bucks *et al*., 1974). When fertilizer is applied through drip system (fertigation), the applied fertilizer is effectively used by the plants as it is placed in effective crop root zone as compared to furrow irrigation system (Miller *et al*., 1976; Locascio and Smajstrala, 1995; Singandhupe *et al*., 2003). In this study, variation in carbon dioxide exchange rates in male and female plant of pointed gourd due to leaf position as well as diurnal variation is being reported for the first time.

Considering the importance of drip irrigation with respect to irrigation water, fertilizer saving and importance of crops in human diet, the experiment was carried out with different levels of irrigation, fertilizer and mulch and to assess the growth habit and physiology aspect of plant in sub-humid climate region of India.

Materials and Methods

Root suckers of locally available pointed gourd (Cuttack culture) were planted in crop geometry of 1.5×1.0 m in plot size of 6×6 m in October 2000 at Research Farm of Water Technology Centre for Eastern Region, Bhubaneswar (20° N, 85°E). Since the crop is dioecious after every ten female plants one male plant was planted. In all, 24 pits per plot with size of 45×45×45 cm was made and Farm Yard Manure at the rate of 10 t ha^{-1} was thoroughly mixed with excavated soil and again it was put into same pits before planting vines. The experimental field was loamy with low in available nitrogen, medium in available phosphorus and potassium. The treatment comprised three irrigation levels i.e., 100, 80 and 60% of Pan Evaporation (PE), three fertilizer levels, i.e., 100, 75 and 50% of the Recommended Dose (RD = 180:90:90 kg NPK ha^{-1}) and two levels of mulch i.e., 7.5 and 15 t ha^{-1}. Irrigation water was applied through drip at 2-day interval by considering crop geometry, 60% wetted area, crop coefficient 0.65, 0.90 and 1.05 from planting to sprouting of leaf, sprouting of leaf to flowering/initiation of fruiting and then flowering/initiation of fruiting to receipt of rains (up to first week of June, 2002). Amount of irrigation water applied was measured through water meter, which was fixed in main line of the drip system. Nitrogen as per level was applied at monthly interval from January 2002 and continued up to August 2002, however phosphorus and potassium was applied as per levels manually after application of urea solution through drip.

For physiological study, the male and female plants from 100% PE, 100% recommended dose and 15 t ha^{-1} treatment was selected. The observations on photosynthesis were recorded in the second year old crop at flowering and fruiting stage on 3.6. 2002. The photosynthetic observations were recorded in five plants using IRGA LICOR 6200. Leaf area of individual leaves was measured in leaf area meter LICOR 3100.

Results and Discussion

Physiological Study

The average length of vine in a male plant was 110 cm as compared to female plant (102 cm) due to the variation in inter-nodal length. The average inter-nodal length of a female plant was 5-6.4 cm whereas in male plants it varied from 6.2-8.4 cm. The individual leaf area were also more in male plants as compared to the female plants. In male and female plants the bottom most leaf had lesser leaf area, as it was the first formed leaf (Table 1). The leaf weight per unit leaf area (SLW) was more in female plants as compared to male plants. Though male plants had higher leaf area the leaves had lesser SLW indicating thin leaves with lesser number of cells per unit area.

The data on leaf photosynthesis at different position showed an increase in photosynthesis rate up to leaves at 4th position and there after declined. Conductance also had a gradual increase and maximum was in 4th leaf. An increased photosynthesis and conductance accompanied a decrease in internal carbon dioxide content in up to 9th leaf from top (Table 2). The older leaves (10th to the bottom most) registered a decrease in photosynthesis accompanied by a decrease in conductance and increase in internal carbon dioxide content. The reduced stomata conductance and less carbon dioxide fixation activity due to aging was described as the cause of decline in photosynthesis in aged leaves (Ranjendrudu and Naidu, 1997). The top nine young leaves had a significant correlation of net photosynthesis with conductance (0.884**) and internal carbon dioxide content (-0.6860*). The significant negative correlation between conductance and internal carbon dioxide content indicates better utilization of CO_2 at top nine leaves (r = -0.737*). But the bottom leaves from the 10th position did not have any significant correlation among the measured parameters. There was a significant linear relationship (at 5% level of significance) with photosynthesis and internal carbon dioxide content (Y = -0.306 X+98.86, r = 0.686*) for the upper nine leaves. But the lower leaves did not register any significant relationship.

Diurnal variation in photosynthesis was observed in male and female plants. Sexual differences in carbon dioxide exchange rates have been reported in *Silene latifolia* (Gehring and Monson, 1994). In pointed gourd male plants had a higher photosynthetic rate compared to female plants (Fig. 1c). Similar response was reported in male plants of *Aciphylla glaucescens* (Hogan *et al*., 1998) and *Siparuna grandiflora* (Adrienne *et al*., 2003). In female plants photosynthesis increased gradually and reached a maximum at 1130 h when quantum was around 1200 μmole $m^{-2}s^{-1}$ and again a small increase around 1530 h when the quantum was around 800 μmole $m^{-2}s^{-1}$ (Fig. 1a). Whereas in male plants, an early increase in photosynthesis at 0730 h (quantum 800 μmole $m^{-2}s^{-1}$) and a second peak between 1130-1200 h when the quantum was maximum. A midday depression was observed in photosynthesis in female plants. A concomitant increase in conductance and decrease in internal carbon dioxide content accompanied the increase in photosynthesis in female plants (Fig. 1b). In male plants conductance peaked later after maximum net photosynthesis at early hours (Fig. 1d). This indicates that early increase in photosynthesis in male plants was not due to increase in conductance. The internal CO_2 was high in male plants compared to female plants during early hours. The readily available substrate along with increase in quantum resulted in an increase in photosynthesis rate in male plants, which was much earlier than female plants. The build up of carbon dioxide in male plants may be due to increased

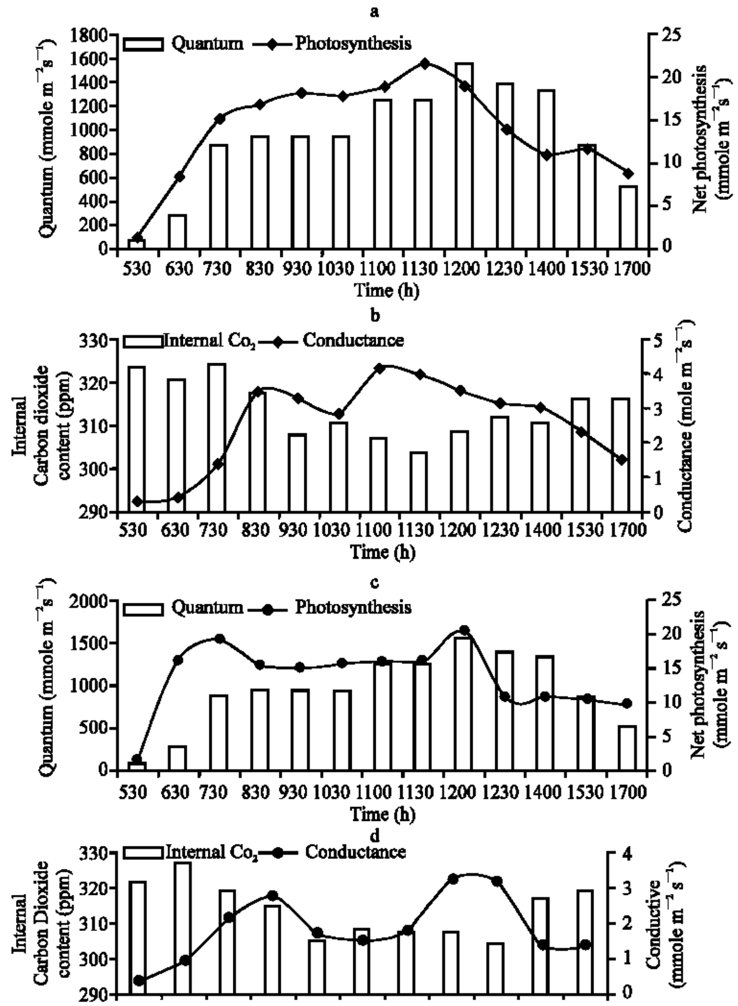

Fig. 1: Diurnal variations in carbon dioxide exchange rates in female (1a and 1b) and male (1c and 1d) plants of pointed gourd

respiration rate in male plants compared to female plants. After the sudden increase in photosynthesis in male plants there was a decline and it was maintained at a steady level before next maximum photosynthesis. In female plants a clear midday depression was expressed after the first maximum in photosynthesis. The regulation of RUBPcase and SPS activity has been detailed as the reasons for mid day decline in photosynthesis (Sinha *et al*., 1997). Dynamic photo inhibition was also described as the cause for reduction in carbon dioxide fixation at midday, when leaves are exposed to maximum amount of light (Osmond, 1994). The depression in photosynthesis in male plants was due to stomata limitation as evident from conductance at that point.

Pointed gourd growth is affected by low temperature as the crop goes in dormancy during winter season. More research works are required on response of photosynthesis at different temperatures and irradiance levels in pointed gourd. The modes of partitioning of carbon fixed in male and female plants

Table 1: Variations in leaf characteristics of male and female plants of pointed gourd with respect to leaf position

	Female		Male	
Leaf position from top	Leaf area (cm^2)	SLW (g cm^{-2})	Leaf area (cm^2)	SLW (g cm^{-2})
1	15.18±2.06	5.23	14.09±1.905	4.00
2	27.13±1.3	6.26	25.12±3.86	4.50
3	31.59±2.75	5.69	39.14±2.22	4.76
4	37.75±2.38	6.66	37.31±2.61	5.16
5	40.02±1.44	5.0	45.35±3.31	4.80
6	38.10±3.35	6.25	40.31±2.22	5.49
7	24.72±5.57	4.85	43.17±2.97	3.90
8	25.98±5.51	6.94	46.56±1.22	3.61
9	27.10±1.57	5.55	48.11±1.76	6.28
10	23.75±4.99	5.49	42.04±3.01	6.32
11	24.24±2.86	5.49	50.20±1.61	5.43
12	28.92±1.52	4.14	47.48±3.12	6.32
13	24.95±4.14	5.05	40.45±2.11	7.20
14	29.39±3.12	4.78	37.37±1.71	6.20
15	28.18±4.12	4.62	26.26±3.63	6.80
16	15.02±1.02	8.0	23.00±3.09	7.60
17	17.24±2.19	8.65	13.45±3.18	6.41
18	16.78±3.11	7.19	13.67±1.11	6.70
19	15.17±1.09	7.93	12.12±1.16	7.50

Each value is the mean of five observations

Table 2: Variation in carbon dioxide exchange rates in pointed with respect to leaf position

Leaf position from top	Photosynthesis (µmol m^{-2} s^{-1})	Conductance (µmol m^{-2} s^{-1})	Internal carbon dioxide content (ppm)
1	9.00±0.12	0.872±0.98	299.8±1.01
2	10.23±1.31	0.996±1.02	284.1±1.06
3	10.78±0.92	1.151±1.02	288.3±1.11
4	17.59 ±1.06	1.236±0.92	281.9±2.22
5	13.83±1.12	1.260±1.02	277.4±3.12
6	10.57±0.66	0.966±0.99	281.9±2.12
7	9.06±0.16	0.855±1.22	294.0±3.99
8	8.22±1.22	0.775±1.11	290.8±1.26
9	7.39±1.61	0.766±0.98	292.21±3.16
10	7.78±1.22	0.614±1.61	289.3±2.12
11	8.66±1.23	0.861±1.22	329.0±1.41
12	9.27±1.98	0591±1.11	335.2±3.11
13	8.16±1.23	0.591±0.92	314.1±1.22
14	3.33±1.26	0.820±1.11	312.75±2.16
15	3.04±2.01	0.516±1.91	330.0±1.61
16	2.52±2.29	0.507±2.11	304.9±1.11
17	5.87±2.16	0.369±2.01	303.1±2.91
18	4.08±2.11	0.567±2.61	317.0±3.21
19	3.66±2.18	0.66±2.01	313.5±3.14

Each value is the mean of five observations

also need to be studied. The photo respiration, cause for low quantum yield need to be explored along with the RUBISCO expression and activity under varying environmental conditions in male and female plants of pointed gourd.

Fruit Yield

Application of irrigation water at the rate of 100% PE through drip at two days interval produced 7.1 and 25.2% higher fruit yield over 80 and 60% PE in which the fruit yield was 4.92 and 4.21 t ha^{-1}, respectively (Table 3). At the same time irrigations applied at 100% PE required 22.97 and 58.58% more irrigation water during dry season period over 80% (47.9 cm) and 60% PE (37.13 cm),

Table 3: Effect of irrigation, fertilizer and mulch on fruit yield (t ha^{-1}) of pointed gourd during 2001-02

	Fertilizer (NPK kg ha^{-1})				Mulch (t ha^{-1})		
Treatment	180:90: 90	135:67.5:67.5	90:45:45	Mean	7.5	15.0	Mean
Drip irrig.							
100% PE	5.70	5.17	4.95	5.27	4.92	5.62	5.27
80% PE	5.31	5.46	3.99	4.92	4.77	5.07	4.92
60% PE	4.48	4.32	3.83	4.21	4.27	4.14	4.21
Mean	5.16	4.99	4.25	-	4.65	4.95	-
Mulch (t ha^{-1})							
7.5	4.97	4.91	4.08	4.65			
15.0	5.35	5.06	4.42	4.95			

LSD (p = 0.05) I = 0.49; F = 0.38; IxF = 0.65; M = 1.13; IxM = 1.45; FxM = 0.68; IxFxM = 1.17

Table 4: Irrigation and fertilizer use efficiency in pointed gourd during 2001-02

Treatment	IWUE (kg fruit ha^{-1} cm^{-1}) applied water	FUE (kg fruit kg^{-1}) of applied NPK	NUE (kg fruit kg^{-1} of applied N)	P/KUE(kg fruit kg^{-1} of applied P or K)
Drip irrig				
100% PE	88.41	20.82	41.65	83.30
80% PE	102.8	19.05	38.10	76.21
60% PE	108.97	16.55	33.12	66.24
LSD (p = 0.05)	9.39	2.17	4.34	8.69
Fertilizer (kg ha^{-1})				
180:90:90	105.37	14.34	28.68	57.37
135:67.5:67.5	105.89	18.47	36.94	73.84
90:45:45	88.91	23.62	47.25	94.51
LSD (p = 0.05)	8.53	1.74	3.47	6.95
Mulch (t ha^{-1})				
7.5	95.94	18.22	36.45	72.90
15.0	104.17	19.39	38.80	77.60
LSD (p = 0.05)	25.59	5.21	10.42	20.84
Interactions:				
LSD (p = 0.05)				
IxF	14.78	3.00	6.01	6.95
IxM	31.06	5.21	10.42	23.17
FxM	14.05	5.78	6.08	12.16
IxFxM	34.34	5.26	10.53	21.06

Note: I = Irrigation level, F = Fertilizer level and M = Mulch level

respectively. Considering the importance of irrigation water during summer season, irrigation at 80% of PE may be followed as the fruit yield is slightly less than 100% PE. The reduction in marginal fruit yield can be compensated by irrigating more area with 22.97% saved water. Application of 180:90:90 kg NPK ha^{-1} in eight splits through drip at monthly interval, produced 3.4 and 21.8% higher fruit yield than 135:67.5: 67.5 kg NPK ha^{-1} (75% RD) and 90:45:45 kg NPK ha^{-1} (50% RD), respectively. So under drip system, fertigation with 75% RD produced comparable fruit yield with 100% RD and saved 25% fertilizer dose as applied fertilizers are placed near the plant root zone and effectively utilized by the plants. In this experiment, it has been observed that application of 75% of the recommended dose of fertilizer with 80% PE produced 5.6% higher fruit yield than irrigations applied at 100% PE with same amount of fertilizer dose (Table 3). Effect of differential quantity of paddy straw mulch did not respond significantly, however application of paddy straw mulch at the rate of 15 t ha^{-1} produced 6.45% higher fruit yield than 7.5 t ha^{-1} paddy straw in which the fruit yield was only 4.65 t ha^{-1}. With regards to interactive effects of irrigation, fertilizers and mulch, the effects of these treatments on fruit yield was non-significant, however application of 180:90:90 kg NPK ha^{-1} with 15 t ha^{-1} paddy straw, influenced the crop with higher magnitude and produced maximum fruit yield of 5.35 t ha^{-1}. Similarly, the magnitude of response of fertilizer on fruit yield was maximum of 24.06% where low amount of fertilizer (90:45:45 kg NPK ha^{-1}) and sufficient amount of soil moisture at 100% PE was maintained throughout the crop growth period.

Fertilizer Use Efficiency

During crop growth period, adequate amount of irrigation water within crop root zone under 100 and 80% PE irrigation schedule enhanced utilization of applied fertilizer by the plants and hence Fertilizer Use Efficiency (FUE is the fruit yield obtained by applying unit amount of fertilizer), Nitrogen Use Efficiency (NUE) and phosphorus/potassium use efficiency was very high. FUE in 100% and 80% PE irrigation schedule was 20.82 and 19.05 kg fruit kg^{-1} applied NPK, respectively. However in 60% PE irrigation schedule, the FUE was statistically reduced to 16.55 kg fruit kg^{-1} NPK. In case of nitrogen and phosphorus or potassium as independent plant nutrients, the effect of these nutrients on fruit yield were quite significant and the NUE in 100 and 80% PE irrigation schedule were 41.65 and 38.10 kg fruit kg^{-1} applied nitrogen, respectively and in the lowest level of irrigation water (60% PE), NUE was only 33.12 kg fruit kg^{-1} applied nitrogen. Similarly in case of phosphorus and potassium, the response on fruit yield was quite high under adequate supply of irrigation water in 100 and 80% PE which was 83.30 and 76.21 kg fruit kg^{-1} of applied phosphorus/potassium in above respective irrigation schedule (Table 4).

Generally under limited supply of plant nutrients in growing media plant absorb more mineralized fertilizer to meet their demand (Yoshida, 1978; Chauhan and Mishra, 1989). It has been observed from the experiment that under lowest level of fertilizer dose i.e., 90:45:45 kg NPK ha^{-1}, FUE, NUE and P/K use efficiency was 23.62 kg fruit kg^{-1} applied NPK, 47.25 kg fruit kg^{-1} of applied nitrogen and 94.51 kg fruit kg^{-1} of applied phosphorus/potassium, respectively. However with increasing fertilizer level from 90:45:45 kg NPK ha^{-1} to 180:90:90 kg NPK ha^{-1}, the FUE, NUE and P/K use efficiency was reduced to 14.34, 28.68 and 57.37 kg fruit kg^{-1} of NPK, nitrogen and phosphorus/potassium, respectively. The effect of differential amount of mulch on FUE, NUE and P/K use efficiency was non-significant and hence any quantity of mulch material (up to 15 t ha^{-1}) may be used to have some 18.22 to 19.39 kg fruit per kg of applied NPK, 36.45 to 38.80 kg fruit kg^{-1} of nitrogen and 72.90 to 77.60 kg fruit kg^{-1} of applied phosphorus/potassium.

Irrigation Water Use Efficiency (IWUE)

Effect of higher amount of irrigation water in 100% PE did not produce proportionate amount of pointed gourd and hence irrigation water use efficiency in 100% PE was 88.41 kg fruit ha^{-1} cm^{-1} applied water but in 80 and 60% PE, the irrigation water use efficiency was higher by 16.27 and 23.25%, respectively as a unit amount of water applied in lower irrigation schedule produced more fruit yield over higher irrigation schedule. In case of differential amount of fertilizer level, the irrigation water use efficiency was statistically non significant between 100% and 75% RD and was found to be 105.37 and 105.89 kg fruit ha^{-1} cm^{-1} of applied irrigation water, respectively but in case of 50% RD the IWUE was drastically reduced by 15.6% (88.91 kg fruit ha^{-1} cm^{-1} applied irrigation water) over 100% RD. The effect of two levels of mulch on IWUE was not effective, however, application of 15 t ha^{-1} straw mulch had 8.6% more IWUE than 7.5 t ha^{-1} straw mulch (Table 4).

In commercial crops, adoption of drip irrigation saves substantial amount of irrigation water and fertilizer as these inputs are costlier resources in crop production. From the present investigation, it is noticed that application of irrigation water through drip system at 80% of pan evaporation, produced equivalent fruit yield of pointed gourd as compared with 100% PE. Hence instead of applying irrigation water to its potential rate, minimizing irrigation water to the extent of 20% of its demand is more than enough to obtain satisfactory fruit yield. Similarly, fertilizer application at the rate of 75% of the recommended dose produced satisfactory fruit yield and it is comparable with 100% of the recommended dose of fertilizer. Thus there is 25% saving of inorganic fertilizer as these fertilizers are placed near the most effective crop root zone and utilized by the plant effectively. Assessment of photosynthesis rate and carbon dioxide concentration in plant and its exchange rate is highly essential to monitor the rate of biomass production, which ultimately converted in to economic yield.

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