EFFECT OF DRIP IRRIGATION AND FERTIGATION LEVELS ON THE YIELD AND QUALITY OF MUSCAT GRAPES (*VITIS VINIFERA*)

EFFET D'IRRIGATION PAR ÉGOUTTEMENT ET DE NIVEAUX DE FERTIGATION SUR LE RENDEMENT ET QUALITÉ DES RAISINS DE MUSCAT (VITIS VINIFERA)

N.Asokaraja[1]

ABSTRACT

The present investigation was taken up with an aim to optimize the dripirrigation requirement and to to determine correct fertigation schedule so as to maximize water and fertilizer use efficiencies along with fruit quality improvement in Muscat grapes. Three levels of dripirrigation were scheduled at 100%, 75% and 50% of computed Irrigation Requirement (IRc) and 3 levels of fertigation were carried out at 125%, 100% and 75% of recommended NPK with imported grades of Water Soluble Fertilizers (WSF) as well as Normal fertilizers (NF) like Urea, Phosphoric acid and Potash. Results from this project showed that optimum dripirrigation scheduling is once in 3 days and at 100% IRc (about 20-25 liters/vine/day) with a total water requirement of 370 to 450 mm in the growing season including effective rainfall. Fertigation with NF was found to be equally superior and cost effective to that of fertigation with WSF. Drip fertigation at 125% of recommended NPK dose was superior to 100% dose both in WSF and NF revealing that there is greater response for enhanced fertilizer dose with Muscat grapes for maximum production. Dripirrigation at 100% IRc was superior to lower levels of 75 and 50%. No. of bunches per vine, number of berries per bunch, berry weight and yield per vine were favourably improved by dripfertigation with WSF. Maximum fruit yield (27.5 tonnes/ha) in Muscat grapes was possible with WSF at 125% dose under higher dripirrigation level of 100% IRc followed by NF (25.86 tonnes/ha).

Fertigation at 75% dose with NF was economical as compared to WSF. Fruit quality of Muscat grapes was greatly improved with higher TSS and total sugar with less acidity by drip fertigation with WSF followed by NF. Maximum gross income was obtained with dripfertigation with WSF at 125% dose, INR 4, 12,500 (US $ 8417) per ha and INR 3, 87,900 (US $ 7914) in case of NF. However, NF has registered higher benefit cost ratio ranging from 1.92 to 2.36 per rupee invested as compared to WSF. Thus drip fertigation with NF was economically superior to WSF in Muscat grapes chiefly grown in Tamil Nadu State in India.

1 - Professor of Agronomy, Directorate of Research, Tamil Nadu Agricultural University, Coimbatore – 641 003, Tamil Nadu, India (www.tnau.ac.in), E-mail: nasokaraja@yahoo.com

RÉSUMÉ MASCULIN

La recherche actuelle est prise dans un but pour optimiser la condition d'irrigation par égouttement et pour déterminer le programme correct de fertigation afin de maximiser des efficacités d'utilisation de l'eau et d'engrais avec l'amélioration de qualité du fruit en raisins de muscat. Trois niveaux d'irrigation par égouttement ont été programmés à 100%, 75% et 50% de la condition calculée d'irrigation (IRC) et 3 niveaux de fertigation ont été effectués à 125%, 100% et 75% de NPK recommandé avec les catégories importées des engrais hydrosolubles (WSF) aussi bien que les engrais normaux (N-F) comme l'urée, acide phosphorique et potasse. Les résultats de ce projet ont prouvé que l'établissement du programme optimum d'irrigation par égouttement est une fois en 3 jours et à IRC 100% (environ 20-25 litres/vigne/jour) avec une condition totale de l'eau de 370 à 450 millimètres dans la saison de croissance comprenant des précipitations efficaces. Fertigation avec N-F s'est avéré également supérieur et rentable à celui du fertigation avec WSF. Le fertigation d'égouttement à 125% de la dose recommandée de NPK était supérieur à la dose de 100% dans WSF et N-F indiquant qu'il y a une plus grande réponse pour la dose augmentée d'engrais avec des raisins de muscat pour la production maximum. L'irrigation par égouttement à IRC 100% était supérieure aux niveaux plus bas de 75 et de 50%. Non. des groupes par vigne, le nombre de baies par groupe, le poids de baie et le rendement par vigne ont été favorablement améliorés par fertigation d'égouttement avec WSF. Le rendement maximum de fruit (27.5 tonnes/ha) en raisins de muscat était possible avec WSF à la dose de 125% sous un niveau plus élevé d'irrigation par égouttement d'IRC 100% suivi de N-F (25.86 tonnes/ha).
Fertigation à la dose de 75% avec N-F était économique par rapport à WSF. La qualité du fruit des raisins de muscat a été considérablement améliorée avec de plus hauts SOLIDES SOLUBLES TOTAUX et le sucre total avec moins d'acidité par fertigation d'égouttement avec WSF suivi de N-F. Le revenu brut maximum a été obtenu avec le fertigation d'égouttement avec WSF à la dose de 125%, à l'INR 4.12.500 (USA $ 8417) par ha et à l'INR 3.87.900 (USA $ 7914) en cas de N-F. Cependant N-F a enregistré un rapport plus élevé de coût d'avantage s'étendant de 1.92 à 2.36 par roupie investie par rapport à WSF. Ainsi le fertigation d'égouttement avec N-F était économiquement supérieur en raisins de muscat principalement cultivés dans l'état de Tamil Nadu en Inde.

1. INTRODUCTION

Production potential of grapes is chiefly governed by the irrigation and fertilization. In India grapes is grown in area of 1.06 lakh ha with a production of 8.8 lakh tonnes, whereas in Tamil Nadu (South India), it is grown in 2630 hectares with a production of 44140 tonnes which is 5% of the total production. However the productivity in Tamil Nadu is 16.78 tonnes per hectare (which is almost double) compared to the national average of 8.28 tonnes per hectare (NHB, 2009-10). Tamil Nadu farmers are following only surface irrigation (check basin) to grapes, which account for more deep percolation losses. However, a grape is highly suited to drip irrigation. In Tamil Nadu only 14% of the grape cultivated area (370 ha) is under drip irrigation as compared to 75% in Maharashtra State (Naresh Modi and Kamal Kishore, 1999). The average daily water requirement per plant (vine) was 24 litres through drip for a spacing of 3.0 x1.5m, which has resulted in an annual water saving of 3700 m^3 corresponding to 19 per cent saving over conventional irrigation (Rao et al., 1999). Replenishment of evaporation losses to 75% under drip irrigation to grapes was sufficient wherein the total water requirement was 712 mm under drip as compared to 942 mm in surface irrigation (Srinivas et al, 1999). Fertigation with

water soluble fertilizers at 80% recommended dose (RDF) through drip in blue grapes at Bangalore improved the TSS, berry size and economized 20% fertilizer, 30% irrigation water besides 119% yield increase (Shivashankar, 1995). Application of water soluble fertilizers at 80% RDF has resulted maximum number of canes (120.31), bunch weight (174.38 g) and fruit yield (21.79 t/ha) as compared to normal fertilizers at 100% dose with basin irrigation (82.13, 127.42 g and 11.59 t/ha respectively).

Water soluble fertilizers were superior to normal straight fertilizers considering fruit quality and yield but the normal fertilizers accounted for higher cost-benefit ratio of 1:2.62 at 100% recommended level (Khan et al., 1999). However in grapes variety Sonaka, the cost benefit ratio with water soluble fertilizers was 1 : 5.4 as against 1 : 3.83 with normal fertilizers (Swapnil Bachchhav, 1995).

It is clear that the water requirements for grapes vary with irrigation methods and evaporative demand of agro-climatic regions in India. Fertigation with water soluble fertilizers and normal fertilizers to grapes offers potential alternate to conventional irrigation and fertilization.

2. MATERIALS AND METHODS

The experimental location is situated at 11^0 N latitude and 77^0 E longitudes at an altitude of 427 m above MSL. Four year old Muscat grapes vines planted at 3.0 x 1.5 m was taken for the investigation. The average rainfall of Coimbatore is 640 mm, received in 47 rainy days. A total of 413.9 mm, 227.8mm and 140.4 mm of rainfall during 1^{st}, 2^{nd} and 3^{rd} cropping periods respectively was received. The mean maximum and minimum temperatures were ranging from 33.7^0C to 23.1^0C. The mean cumulative pan evaporation was 560.4 mm.

The soil of the experimental field was a clay loam with slightly higher pH of 8.15, low in available N (29.2 kg/ha), P (2.56 kg/ha) and medium in available K (200 kg/ha). The soil is saline-alkaline. The irrigation water from bore well had a pH of 7.3 and an EC of 1.50 dSm^{-1}. The study consisted of 3 levels of drip irrigation at 100, 75 and 50% of IRc once in 3 days and 3 levels of fertigation at 125%, 100% and 75% of RDF and 2 forms of fertilizers viz., imported Water Soluble Fertilizers (WSF) and conventional Normal Fertilizers (NF).

2.1. Design and layout of drip fertigation system

From the main pipe (PVC 75 mm OD), a take off with 2" PVC line was made and fitted with a 2" Super Clean mesh filter (25 m^3/hr). The control head consisted Quick Pressure Relief Valve (1.5"), Ventury Assembly, By pass assembly and Plastic Y filter (1") after Ventury. One set of sub main pipes (40mm OD) were laid out along 80 m length in the centre of the field to deliver water on either side (one side for fertigation with WSF and another side for fertigation with NF).

The laterals (16mm OD) were fixed for 25m length covering 3 replications on either side. On line PC drippers of 8 lph were fixed at 0.75 m apart along lateral (33 nos per line). For the purpose of imposing fertigation treatments, the laterals were laid on the surface only.

2.2. Drip irrigation scheduling

Drip irrigation was scheduled once in 3 days at 100, 75 and 50% of the computed water requirement (IRc). Based on the cumulative pan evaporation data once in 3 days, the irrigation water requirement through drip (volume in liters/per vine/once in 3 days) was computed as detailed here under.

IR_C = Computed Irrigation Requirement (mm)

$$IR_C = Epan \times Kp \times Kc \times A \times Wp$$

Where

Epan = Pan Evaporation rate (mm) (U.S.Open Pan Evaporimeter)
Kp = Pan Co-efficient (0.75)
Kc = Crop Co-efficient (Initial Stage- 0.30; Mid stage - 0.85; Late stage - 0.45, Adopted from FAO Paper, 1998, Vol.56)
A = Area of the plant (3 x 1.5 m = 4.5m^2)
Wp = Wetted percentage (40 per cent, from FAO Paper, 1980, Vol.36)

The experiments were laid out in Split plot design with three replications. The individual plot size was 74.7 m^2 (8.3 m x 9.0 m)

2.3. Fertigation scheduling

Fertigation at 125, 100 and 75% of RDF at 330:266:990 NPK kg/ha through ventury was carried out once in 3 days with water soluble fertilizers (WSF). Mono Ammonium Phosphate (12:61:0) was applied 7 times once in 3 days during 1-20 Days After Pruning (DAP) to supply high P requirement. Polyfeed (19:19:19) was applied 7 times once in 3 days during 21-40 DAP to supply NPK during growth phase for normal requirement. Multi-K (13-0-45) was applied 13 times once in 3 days during 41-80 DAP and 3 times once in 3 days during 81-90 DAP to supply high K requirement during berry growth and ripening stage. Urea and Sulphate of Potash (0:0:50) were supplied to meet the balance requirement of N & K respectively at corresponding stages. Similarly fertigation was done with Normal Fertilizers (NF) once in 3 days at 125, 100 and 75% of RDF at 330:266:990 NPK kg/ha. Ortho Phosphoric acid (86% P_2O_5) was supplied once in 3 days during first two stages 1-40 days after pruning). Urea (46% N) was applied once in 3 days throughout from 1-90 DAP. Sulphate of Potash (52% K) was applied once in 3 days throughout from 1-90 DAP. Nutrient doses were kept at same level for both WSF & NF fertigation for corresponding stages. The details of the fertigation schedule adopted in this investigation are illustrated in Table 1 & Table 2.

Table 1. Fertigation Schedule for Muscat grapes (WSF) at 100% dose (Programme de Fertigation pour les raisins de muscat (WSF) à 100%)

Stage	Fertilizer Form	Fertilizer grade			Dose/ ha/ 3 days	Total Qty Kg/ha	Nutrients (Kg/ha)		
		N	P	K			N	P	K
1 to 20	MAP	12	61	0	48.57	340	40.80	207.40	0.00
	SOP	0	0	50	42.86	300	0.00	0.00	156.00
	Urea	46	0	0	51.43	360	165.60	0.00	0.00
21-40	PF	19	19	19	44.29	310	58.90	58.90	58.90
	SOP	0	0	50	42.86	300	0.00	0.00	156.00
41-80	Multi-K	13	0	46	28.85	375	48.75	0.00	172.50
	SOP	0	0	50	57.69	750	0.00	0.00	390.00
81-90	Multi-K	13	0	46	41.67	125	16.25	0.00	57.50
Total							**330.30**	**266.30**	**990.90**

Note: MAP - Mono Ammonium Phosphate; SOP (WSF) - Soluble Sulphate of Potash; PF - Poly feed; Multi-K- Potassium Nitrate

Table 2. Fertigation schedule for Muscat grapes (NF) at 100% dose (Programme de Fertigation pour les raisins de Muscat (N-F) à la dose de 100%)

Stage	Fertilizer Form	Fertilizer grade			Dose/ha/ 3 days	Total Qty Kg/ha	Nutrients (Kg/ha)		
		N	P	K			N	P	K
1 to 20	Ortho H_3PO4	0	86	0	31.86	223.0	0.00	191.78	0.00
	Urea	46	0	0	61.43	430.0	197.80	0.00	0.00
	SOP	0	0	50	44.29	310.0	0.00	0.00	161.20
21-40	Ortho H_3PO4	0	86	0	11.43	80.0	0.00	68.80	0.00
	Urea	46	0	0	18.57	130.0	59.80	0.00	0.00
	SOP	0	0	50	60.00	420.0	0.00	0.00	218.40
41-80	Urea	46	0	0	8.46	110.0	50.60	0.00	0.00
	SOP	0	0	50	81.92	1065.0	0.00	0.00	553.80
81-90	SOP	0	0	50	36.67	110.0	0.00	0.00	57.20
	Urea	46	0	0	16.00	48.0	22.08	0.00	0.00
Total							**330.28**	**260.58**	**990.60**

Note: SOP (NF) - Sulphate of Potash

3. RESULTS AND DISCUSSION

Observations were made in Muscat Grapes on yield characters, fruit yield and fruit quality, water use, fertilizer use and economics as influenced by drip irrigation and fertigation treatments in 3 crops. The field experimental view with Muscat grapes plantation is depicted in Fig.1.

Figure 1. Muscat grapes plantation at the experimental site (Plantation de raisins de muscat à l'emplacement experimental)

3.1. Yield characters

3.1.1. Number of bunches per vine

Significant differences were observed between WSF and NF and drip irrigation and fertigation levels on the number of bunches per vine in Muscat grapes. Drip irrigation at 100% IRc was significantly superior to 75 and 50% levels. Similarly fertigation at 125%

RDF was significantly superior to 100 and 75% doses. WSF was superior to NF in registering significantly higher number of bunches per vine under drip irrigation at 100% IRc + fertigation at 125% RDF treatment ($S_1I_1F_1$, 33.40) followed by the same treatment with NF at 125% RDF ($S_2I_1F_1$, 33.20) (Table 3). Highest number of bunches per vine (30.06) was recorded with WSF when drip irrigation was scheduled at 100% IRc. This implies that Muscat grapes having higher transpiration demand responds to well for higher drip irrigation regime as compared to 75 and 50% levels. While comparing farmers practice, the wetted soil volume is nearly 50% less under drip irrigation at 100 % IRc, due to non-wetted area between Vine rows. Further reduction in wetting regime (lesser than 100% IRc) under under drip irrigation (i.e 75 and 50% IRc) would result only partial wetting thus limiting potential root development (Ben Ami Bravdo, 1995).

3.1.2. Number of berries per bunch

Among sources of fertilizers, WSF exhibited profound influences as compared to NF. Drip irrigation at 100% IRc + fertigation with WSF at 125% ($S_1I_1F_1$) was significantly superior in registering higher number of berries per bunch (90.24), whereas In case of NF, maximum number of berries was only 80.89 berries for the corresponding treatment which is 10.36% lesser compared to WSF (Table 3). The differential performance in bunch setting with water soluble fertilizer and normal fertilizers are illustrated in Fig 2. The increase in number of berries with WSF is chiefly attributed to high solubility, mobility in soil and plant resulting in better uptake of major nutrients compared to NF having high salt index (Swapnil Bachchhav, 1995).

3.1.3. Berry weight

The weight of individual berry is an important quality factor. In the present investigation, WSF has registered significantly higher average weight of berries under drip irrigation at 100% IRc + fertigation at 125% ($S_1I_1F_1$, 3.63 g) which was on par with drip irrigation at 100% IRc + fertigation with WSF at 100% ($S_1I_1F_2$, 3.59 g). While comparing NF, the average berry weight was only 3.51 g under higher drip irrigation and fertigation level ($S_2I_1F_1$) (Table 4).

Fertigation with WSF at 125% dose

Fertigation with NF 125% dose

Figure 2. Bunch view with water soluble fertilizer and normal fertilizer
(Liez la vue avec de l'engrais hydrosoluble et l'engrais normal)

This implies that Water Soluble Fertilizers are proving their superiority over Normal Fertilizers by registering 0.12 g more berry weight due to their easy availability within the reach of active roots of grapes.

3.1.4. Bunch weight

Bunch weight in Muscat grapes was significantly altered due to forms of fertilizers, drip irrigation and fertigation levels. In first crop, both WSF and NF were found to be equally superior in registering higher average bunch weight especially at higher levels. In case of WSF, drip irrigation at 100% IRc + fertigation with WSF at 125% ($S_1I_1F_1$) has registered higher average bunch weight of 359.42 g which was on par with WSF at 100% dose ($S_1I_1F_2$, 357.21 g) followed by fertigation with NF at 125% ($S_2I_1F_1$, 356.80 g). From this it is clear that fertigation with WSF at 100% dose is superior to NF even at 125% dose. Owing to 100% solubility, greater availability of plant nutrients from WSF at point source of application through drip system might have contributed for more bunch weight in Muscat grapes as compared to NF (Table 4). In the second crop also, similar trend could be noticed. Drip irrigation at 100% IRc (mean, 327.849 g) was on par with 75% IRc (317.284 g) in case of WSF, whereas it was not on par with 75% IRc in case of NF. Fertigation with both forms of fertilizers (WSF and NF) at 75% dose was significantly inferior (nearly 8% less) to higher doses (303.615 g).

Table 3. Number of bunches per vine and number of berries per bumch in Muscat Grapes (Nombre de groupes par vigne et nombre de baies par bumch en muscat raisins)

Treatments	Number of bunches per vine			Number of berries per bunch		
S1- WSF	I crop	II crop	III crop	I crop	II crop	III crop
I1F1-Drip 100% + Fertgn 125%	33.40	34.07	30.06	90.24	97.67	85.73
I1F2-Drip 100% + Fertgn 100%	33.10	31.13	29.79	87.23	94.33	82.87
I1F3-Drip 100% + Fertgn 75%	33.00	27.30	29.70	85.61	79.33	81.33
I2F1-Drip 75% + Fertgn 125%	32.80	30.07	29.52	82.24	84.33	78.13
I2F2-Drip 75% + Fertgn 100%	32.60	25.40	29.34	77.90	83.67	74.01
I2F3-Drip 75% + Fertgn 75%	32.30	23.40	29.07	74.54	77.33	70.81
I3F1-Drip 50% + Fertgn 125%	32.20	25.33	28.98	72.36	74.33	68.74
I3F2-Drip 50% + Fertgn 100%	32.10	24.00	28.89	70.12	73.00	66.61
I3F3-Drip 50% + Fertgn 75%	32.00	22.27	28.80	68.59	74.00	65.16
S2- NF						
I1F1-Drip 100% + Fertgn 125%	33.20	31.47	29.88	80.89	85.33	77.65
I1F2-Drip 100% + Fertgn 100%	33.00	29.33	29.70	78.24	83.00	75.11
I1F3-Drip 100% + Fertgn 75%	32.90	25.13	29.61	75.21	61.00	72.20
I2F1-Drip 75% + Fertgn 125%	32.60	27.40	29.34	73.65	66.00	70.70
I2F2-Drip 75% + Fertgn 100%	32.50	26.93	29.25	73.68	55.67	70.73
I2F3-Drip 75% + Fertgn 75%	32.30	22.27	29.07	72.14	53.33	69.25
I3F1-Drip 50% + Fertgn 125%	32.10	23.53	28.89	70.10	59.00	67.30
I3F2-Drip 50% + Fertgn 100%	32.00	23.87	28.80	67.98	53.00	65.26
I3F3-Drip 50% + Fertgn 75%	31.90	20.20	28.71	65.21	50.00	62.60
	CD (0.05)	CD (0.05)	CD (0.05)	CD (0.05)	CD (0.05)	CD (0.05)
S	0.001	NS	0.007	0.800	6.350	1.800
I	0.031	1.369	0.028	2.760	3.32	2.20
SI	0.002	NS	0.0001	1.390	NS	1.023
F	0.007	1.447	0.003	2.260	3.649	1.402
SF	0.002	NS	0.004	NS	NS	NS
IF	0.005	NS	0.005	NS	6.320	NS
SIF	0.004	NS	0.007	2.400	NS	NS

3.1.5. Fruit yield per vine

The yield per vine in Muscat grapes is an important attribute which ultimately decides the yield of the crop. In first crop, significant and favourable influences were recorded among forms of fertilizers, drip irrigation and fertigation levels.

Water Soluble Fertilizers have shown their superiority over NF in producing higher fruit yield per vine. Drip irrigation at 100% IRc + fertigation with WSF at 125% dose ($S_1I_1F_1$) produced highest fruit yield of 12.253 kg per vine among all treatment combinations. Next to this, NF has registered 11.50 kg per vine under drip irrigation at 100% IRc + fertigation at 125% level ($S_2I_1F_1$) (Table 3). This difference of 0.75 kg per vine with WSF has contributed for the yield increase of 6.5% compared to NF. Drip irrigation at 100% IRc was significantly superior to other levels in recording higher fruit yield of 10.076 kg per vine as compared to 9.099 kg and 8.489 kg per vine under 75 and 50% IRc respectively. Fertigation at 125% dose was significantly superior to 100 and 75% doses (9.718, 9.233 and 8.713 kg under 125, 100 and 75% fertigation levels respectively).

Table 4. Average Berry weight and Bunch weight in Muscat grapes
(Poids moyen de baie et poids de groupe en raisins de Muscat)

Treatments	Average Berry weight (g)			Bunch weight (g)		
S1- WSF	I crop	II crop	III crop	I crop	II crop	III crop
I1F1-Drip 100% + Fertgn 125%	3.630	3.557	3.449	359.416	337.840	305.504
I1F2-Drip 100% + Fertgn 100%	3.590	3.510	3.587	357.213	335.790	303.629
I1F3-Drip 100% + Fertgn 75%	3.480	3.410	3.306	338.623	318.362	287.830
I2F1-Drip 75% + Fertgn 125%	3.330	3.263	3.164	351.496	330.455	298.773
I2F2-Drip 75% + Fertgn 100%	3.310	3.244	3.145	344.906	324.201	293.171
I2F3-Drip 75% + Fertgn 75%	3.290	3.224	3.126	328.790	308.953	279.472
I3F1-Drip 50% + Fertgn 125%	3.200	3.136	3.040	343.416	322.798	291.903
I3F2-Drip 50% + Fertgn 100%	3.000	2.940	2.850	334.123	314.120	284.005
I3F3-Drip 50% + Fertgn 75%	2.900	2.842	2.755	317.603	298.589	269.963
S2- NF						
I1F1-Drip 100% + Fertgn 125%	3.510	3.405	3.335	356.796	335.378	303.278
I1F2-Drip 100% + Fertgn 100%	3.490	3.385	3.155	352.143	331.028	299.323
I1F3-Drip 100% + Fertgn 75%	3.390	3.288	3.221	328.446	308.696	279.180
I2F1-Drip 75% + Fertgn 125%	3.190	3.094	3.031	342.636	322.032	291.241
I2F2-Drip 75% + Fertgn 100%	3.000	2.910	2.850	338.710	318.378	287.905
I2F3-Drip 75% + Fertgn 75%	2.940	2.852	2.793	318.870	299.686	271.040
I3F1-Drip 50% + Fertgn 125%	2.870	2.784	2.727	339.113	318.757	288.248
I3F2-Drip 50% + Fertgn 100%	2.740	2.658	2.606	332.456	312.553	282.588
I3F3-Drip 50% + Fertgn 75%	2.550	2.474	2.423	305.706	287.404	259.850
	CD (0.05)	CD (0.05)	CD (0.05)	CD (0.05)	CD (0.05)	CD (0.05)
S	0.027	0.002	0.040	3.580	6.315	5.549
I	0.099	0.019	0.129	12.730	11.887	10.822
SI	0.047	0.004	NS	NS	NS	NS
F	0.109	0.002	0.087	14.740	7.175	6.486
SF	NS	0.003	NS	NS	NS	NS
IF	NS	0.004	NS	NS	NS	NS
SIF	0.082	0.005	NS	NS	NS	NS

3.1.6. Fruit yield

Fruit yield in grapes is the function of number of bunches per vine, number of berries per bunch, berry weight, bunch weight, yield per vine and the population. With the present

investigation optimum fertigation, drip irrigation levels and forms of fertilizers have been standardized. The correct choice of fertilizer forms with scheduling through optimum drip irrigation volume and dosing of fertilizers would definitely improve the yield in Muscat grapes over conventional practices by the farmers. The view of the experimental field with bunches nearing harvest is shown in Fig 3.

Figure 3. Grape fruit at maturity with water soluble fertilizer (Fruit de raisin à la maturité avec de l'engrais hydrosoluble)

The results showed that the highest fruit yield of 25.03 tons ha^{-1} was registered with WSF as compared to 21.66 tons ha^{-1} only under NF. In case of drip irrigation levels, drip irrigation at 100% IRc was significantly superior to 75 and 50% IRc levels. A mean of 24.76 tons ha^{-1} was recorded under 100% IRc as compared to 22.98 tons ha^{-1} and 22.29 tons ha^{-1} respectively under 75 and 50% IRc. With regard to fertigation levels, drip fertigation at 125% dose was on par with 100% dose but significantly superior to 75% dose.

The interaction among the forms of fertilizers, drip irrigation and fertigation levels showed that drip irrigation at 100% IRc + drip fertigation with WSF at 125% dose and ($S_1I_1F_1$) has recorded significantly an outstanding yield of 27.50 tons ha^{-1}. Under NF, drip irrigation at 100% IRc + drip fertigation at 125% dose has recorded a yield of 25.86 tons ha^{-1}. On equivalent input basis (water + fertilizer) to grapes, (i.e WSF & NF with drip at 100 IRc + fertigation at 125% RDF S_1 / $S_2I_1F_2$), an increase in fruit yield of 10.99% was achieved with WSF over NF (Table.5). This increase with WSF is primarily attributed to increased water and nutrient availability, aeration, number of root tips and transport from roots to shoots similar to the earlier findings (Ben Ami Bravdo, 1995).

4. Water consumption under drip system in Muscat grapes

Total cumulative pan evaporation (CPE) during the 1st cropping period was 583.3 mm. The total water requirement including effective rainfall was 369.8, 344.7 and 319.5 mm under drip irrigation levels at 100, 75 and 50% levels respectively in first crop (Table 6). In second cropping period, the total CPE was 591.7 mm with an effective rainfall of 124.1 mm. The computed irrigation requirement (IRc) through drip was 330.3, 247.7 and 165.1 mm under 100, 75 and 50% IRc respectively. Hence the total water used (Drip irrigation + effective rainfall) was 454.4, 371.8 and 289.2 mm at 100, 75 and 50% IRc respectively, Fig. 4.

Table 5. Yield per vine and Fruit yield in Muscat grapes (Le rendement par vigne et le fruit rapportent en raisins de Muscat)

Treatments	Fruit yield (kg per vine)			Fruit yield (tonnes ha^{-1})		
S1- WSF	I crop	II crop	III crop	I crop	II crop	III crop
I1F1-Drip 100% + Fertgn 125%	12.250	9.922	10.964	27.500	22.065	24.361
I1F2-Drip 100% + Fertgn 100%	11.754	8.879	10.317	26.870	19.729	22.924
I1F3-Drip 100% + Fertgn 75%	10.930	7.678	9.637	25.040	17.059	21.414
I2F1-Drip 75% + Fertgn 125%	11.290	8.290	9.791	26.010	18.421	21.755
I2F2-Drip 75% + Fertgn 100%	11.100	7.239	9.170	23.670	16.086	20.376
I2F3-Drip 75% + Fertgn 75%	10.500	6.710	8.821	23.790	14.909	19.600
I3F1-Drip 50% + Fertgn 125%	10.654	7.265	8.982	22.350	16.143	19.957
I3F2-Drip 50% + Fertgn 100%	10.478	6.709	8.648	22.470	14.907	19.216
I3F3-Drip 50% + Fertgn 75%	10.200	6.020	8.222	20.890	13.377	18.269
S2- NF						
I1F1-Drip 100% + Fertgn 125%	11.500	9.332	10.500	25.860	20.738	23.332
I1F2-Drip 100% + Fertgn 100%	11.150	8.223	9.864	24.213	18.272	21.918
I1F3-Drip 100% + Fertgn 75%	10.780	7.078	9.175	21.940	15.727	20.387
I2F1-Drip 75% + Fertgn 125%	11.012	7.780	9.375	24.170	17.286	20.832
I2F2-Drip 75% + Fertgn 100%	10.751	7.274	9.031	23.520	16.163	20.067
I2F3-Drip 75% + Fertgn 75%	9.245	6.203	8.407	21.040	13.782	18.680
I3F1-Drip 50% + Fertgn 125%	10.050	6.941	8.698	21.890	15.422	19.328
I3F2-Drip 50% + Fertgn 100%	9.113	6.532	8.369	20.450	14.473	18.597
I3F3-Drip 50% + Fertgn 75%	9.002	5.938	8.013	18.540	13.193	17.804
	CD (0.05)	CD (0.05)	CD (0.05)	CD (0.05)	CD (0.05)	CD (0.05)
S	0.110	NS	0.224	0.538	NS	0.497
I	0.310	0.304	0.286	0.924	0.675	0.635
SI	0.200	NS	NS	0.655	NS	NS
F	0.280	0.457	0.178	0.399	1.015	0396
SF	0.200	NS	NS	NS	NS	NS
IF	NS	NS	NS	NS	NS	NS
SIF	NS	NS	NS	0.979	NS	NS

In the third crop also, the total CPE was 556.3 mm with an effective rainfall of 88.7 mm. The total water used (drip irrigation + effective rainfall) under 100, 75 and 50% IRc (drip irrigation treatments I1, I2 and I3) was 403.9, 325.1 and 246.3 mm respectively. In third crop the peak drip irrigation requirement was 65.98, 49.49 and 32.99 litres/ vine once in 3 days at 100, 75 and 50% IRc respectively during 15th of Aug 2005. From this clear that for Muscat grapes, drip irrigation requirement is 21.99 litres per vine per day at 100% ET replenishment level. For maximum fruit yield in grapes, drip irrigation at 100% IRc was essential as could be seen growth and yield characters in Muscat grapes as discussed above. However compared to conventional irrigation (40 litres / vine), there is water saving of 19% under drip irrigation (Rao et al, 1999).

Table 6. Drip irrigation requirement of Muscat grapes (Condition d'irrigation par égouttement des raisins de Muscat)

	I crop		II crop		III crop	
Treatments	**Drip irrigation Requirement (mm)**	**Total Water Requirement (mm) ***	**Drip irrigation Requirement (mm)**	**Total Water Requirement (mm)**	**Drip irrigation Requirement (mm)**	**Total Water Require-ment (mm)**
S1- WSF						
I1F1	100.6	369.8	330.3	454.4	315.2	403.9
I1F2	100.6	369.8	330.3	454.4	315.2	403.9
I1F3	100.6	369.8	330.3	454.4	315.2	403.9
I2F1	75.5	344.7	247.7	371.8	236.4	325.1
I2F2	75.5	344.7	247.7	371.8	236.4	325.1
I2F3	75.5	344.7	247.7	371.8	236.4	325.1
I3F1	50.3	319.5	165.1	289.2	157.6	246.3
I3F2	50.3	319.5	165.1	289.2	157.6	246.3
I3F3	50.3	319.5	165.1	289.2	157.6	246.3
S2- NF						
I1F1	100.6	369.8	330.3	454.4	315.2	403.9
I1F2	100.6	369.8	330.3	454.4	315.2	403.9
I1F3	100.6	369.8	330.3	454.4	315.2	403.9
I2F1	75.5	344.7	247.7	371.8	236.4	325.1
I2F2	75.5	344.7	247.7	371.8	236.4	325.1
I2F3	75.5	344.7	247.7	371.8	236.4	325.1
I3F1	50.3	319.5	165.1	289.2	157.6	246.3
I3F2	50.3	319.5	165.1	289.2	157.6	246.3
I3F3	50.3	319.5	165.1	289.2	157.6	246.3

***** Total water requirement includes effective rainfall of 269.2 mm, 124.1 mm, 88.7 mm in I, II and III crop respectively.

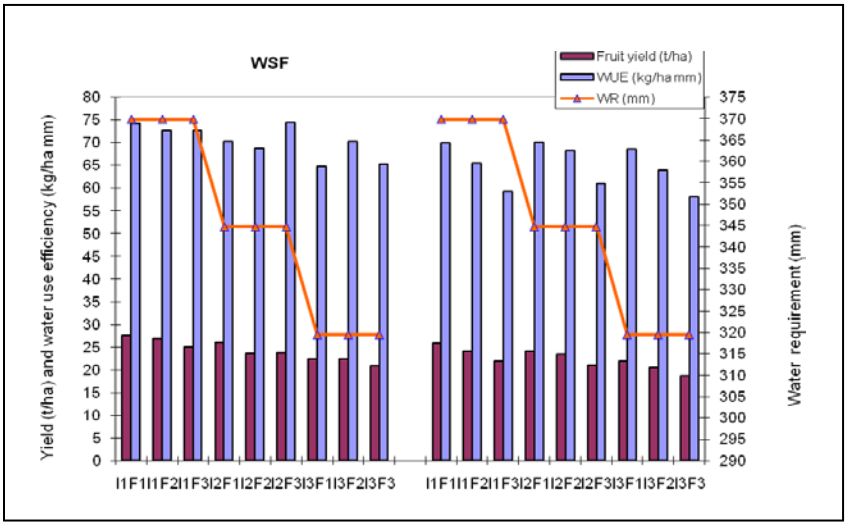

Figure 4. Fruit yield, water requirement and water use efficiency in muscat grapes (I crop) (Le rendement de fruit, la condition de l'eau et l'eau emploient l'efficacité dans des graphiques de muscat (la récolte d'I)

5. Fertilizer use efficiency (FUE)

Fertilizer use efficiency was computed considering the fruit yield and total NPK applied per hectare by drip fertigation. Of course the doses in each levels under WSF and NF were similar (125%, 100% and 75% levels) but the forms of fertilizers applied were different.

The total NPK nutrients supplied by fertigation both in WSF and NF was 330:266:990 (1586 NPK Kg/ha) at 100% dose (F2) and 1982.5 kg at 125% dose and 1189.5 kg at 75% dose. Under this evaluation, in Ist crop, among the forms of fertilizers, WSF was significantly superior to NF with a mean higher FUE of 15.862 kg fruit / kg nutrient (8.98% increase) as compared to NF with 14.554 kg fruit / kg nutrient. In both forms of fertilizers viz., WSF and NF, higher FUE was associated with lower fertigation dose of 75% as compared to 100 and 125% fertigation doses. This is exactly opposite trend of fruit yield obtained. Among fertigation levels, WSF at 75% dose has registered significantly higher FUE of 21.886 kg fruit/kg nutrient applied as compared to NF at the same 75% dose (18.445 kg fruit / kg nutrient). In both forms of fertilizers, fertigation at 125% dose has registered significantly lower mean FUE of 12.463 kg fruit / kg nutrient as compared 14.837 and 18.323 kg fruit / kg nutrient applied at 100 and 125% doses respectively. Similar to this finding, it is reported that the average NPK use efficiency was highest under schedule-I (40% NPK dose) compared to higher fertigation doses in Thompson seedless grapes (Jagdev Sharma et al. 2008).

Among the drip irrigation levels, I1-drip at 100% IRc has registered significantly higher FUE of 16.572 kg fruit/kg nutrient to other levels (15.175 and 13.875 kg fruit / kg nutrient at 75 and 50% IRc respectively). Similar trend was recorded in 2nd and 3rd crops. The relationship between fruit yield, fertilizer use efficiency and fertigation levels with WSF and NF is illustrated in Fig.5.

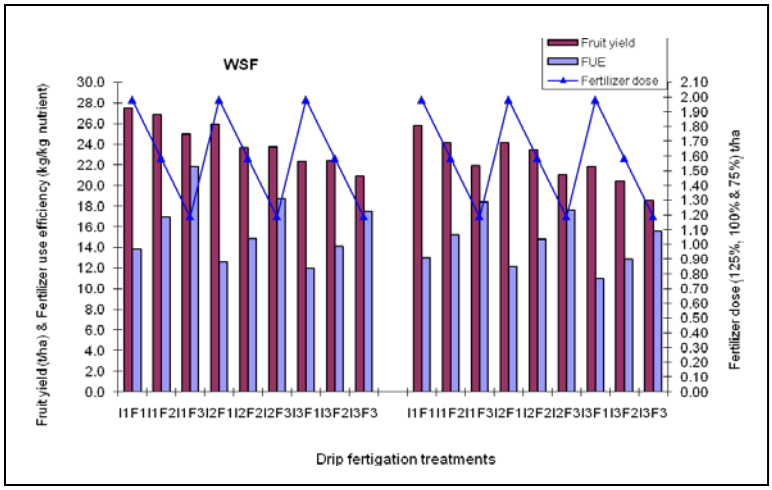

Figure 5. Fertilizer use efficiency, fertigation does and fruit yield in Muscat grapes (I crop) (L'efficacité d'utilisation d'engrais, fertigation fait et rendement de fruit en raisins de muscat (la récolte d'I)

6. Fruit quality in Muscat grapes

6.1 Total Soluble solids, Total sugar and Acidity

Results from the present investigation showed that the fruit quality in Muscat grapes was favourably improved due to forms of fertilizers, drip fertigation and drip irrigation levels. In first crop, the TSS content in fruits was significantly varying due to fertigation with WSF and NF. The highest TSS (16.91%) was registered with WSF under drip irrigation at 100% IRc + fertigation at 125% dose as compared to16.57% similar treatment with NF.

With regard to Total sugar content in Muscat grapes, WSF were significantly superior to NF in registering higher Total sugar per cent (14.96%) with drip irrigation at 100% IRc + fertigation at 125% dose. The Total sugar content under NF was 14.80% only. In case of fruit acidity, fertigation with WSF and NF at higher dose of 125% were equally found to be superior in registering least acidity of 0.45% and 0.44% respectively as shown in Fig.6.

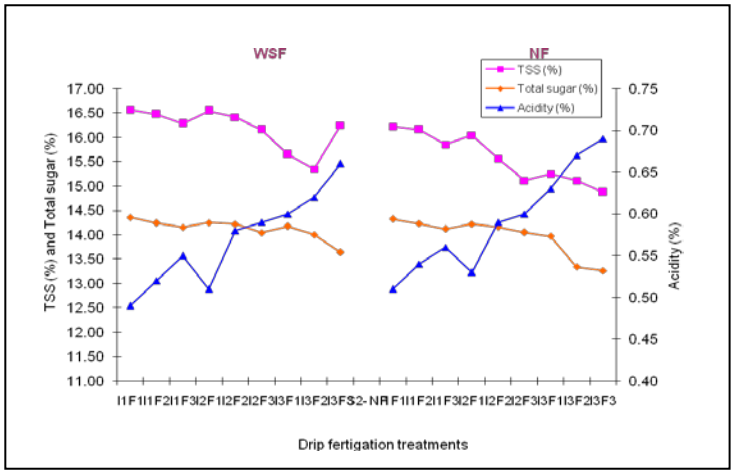

Figure 6. Fruit quality as influenced by fertigation with WSF and NF in Muscat grapes (III crop) (Qualité du fruit comme influencée par fertigation avec WSF et N-F en raisins de muscat (III récolte)

6.2. Shot berries (per cent)

The average number of shot berries was lower in WSF as compared to NF (7.11 and 8.05% respectively).

In first crop, Water soluble fertilizers at 125% dose + drip irrigation at 100% IRc ($S_1I_1F_1$) has registered significantly lowest per cent of shot berries (5.27%). While under NF (fertigation at 125% dose + drip irrigation at 100% IRc ($S_2I_1F_1$) the per cent shot berries was 6.12%.

6.3. Unripe berries

Fertigation with WSF has improved the quality of grapes with minimum per cent of unripe berries which is an essential character in marketing point of view. In first crop, the lowest per cent of unripe berries were recorded under fertigation with WSF at 125% RDF + drip irrigation at 100% IRc ($S_1I_1F_1$ 1.75%) followed by same treatment with NF ($S_2I_1F_1$, 1.75%). Both forms of fertilizers viz., WSF and NF by means of fertigation in Muscat grapes has improved the fruit quality which is essential for better market price.

7. Economics of drip fertigation in Muscat grapes

7.1. Cost of drip fertigation system

The drip irrigation system along with fertigation unit for Muscat grapes (at a spacing of 3 x 1.5 m) was Rs.39706 per hectare. While considering the life of the system for 10 years (well maintained in case of perennial crops like grapes), the annualized cost (which includes depreciation, annual interest @14.5%, repairs and maintenance@5%) was only Rs.9728 per hectare. Hence the annualized cost of drip system with fertigation assembly for grapes was Rs.9728 per hectare both for WSF (S1) and NF (S2).

7.2. Cost of Water Soluble and Normal Fertilizers

Among the two forms of fertilizers, WSF is costlier than NF where in the total fertilizer cost alone was Rs. 114695, Rs. 91756 and Rs. 68817 ha^{-1} at 125%, 100% and 75% NPK doses respectively. Normal fertilizers (with a combination of Urea for N, Ortho Phosphoric acid for P and Muriate of Potash for K) are nearly 1.5 times less costlier than WSF wherein the per ha investment towards fertilizer was Rs. 82394, Rs. 65208 and Rs. 49417 ha^{-1} at 125%, 100% and 75% NPK doses respectively.

7.3. Seasonal total cost of cultivation

7.3.1. Water soluble fertilizers (WSF)

The seasonal total cost of cultivation which includes cost of drip fertigation system + cost of WSF + cost of cultivation for grapes was Rs.1,84,876, 1,61,937 and 1,38,998 per hectare under 125%, 100% and 75% RDF (330:266:990 kg/ha) respectively.

7.3.2. Normal fertilizers (NF)

In case of NF, the seasonal total cost of cultivation which includes cost of drip fertigation system + cost of WSF + cost of cultivation for grapes was Rs.1,62,303, 1,45,117 and 1,29,326 per hectare under 125%, 100% and 75% RDF (330:266:990 kg/ha) respectively.

7.4. Gross Income from the Fruit yield:

Gross income was arrived out taking into consideration the price of fruit at prevailing market rates and the fruit yield in respective treatments. In first crop, among the two forms of fertilizers, highest gross income of Rs.4,12,500 was achieved with WSF under drip irrigation at 100% + fertigation at 125% dose ($S_1I_1F_1$) as compared to Rs.3,87,900 per hectare with NF in the same treatment. The gross income from other levels of fertigation both under WSF and NF are relatively lower. This was mainly due to the high order of fruit yields under higher levels of fertigation (Swapnil Bachchhav. 1995). In second crop also the highest gross income was associated with fertigation at 125% dose with WSF ($S_1I_1F_1$,Rs 330750 per hectare), followed by NF at 125% dose ($S_2I_1F_1$,Rs 3,11,100 per hectare). In third crop also, the highest gross income was associated with fertigation at 125% dose with WSF ($S_1I_1F_1$,Rs 365415 per hectare), followed by NF at 125% dose ($S_2I_1F_1$,Rs 3,49,979 per hectare).

7.5. Benefit cost ratio

Contrary to the gross income obtained, the gross benefit cost ratio (considering the gross income and seasonal total cost of cultivation) showed reverse trend in respect of fertigation doses. The benefit cost ratio was higher under 75% fertigation level as compared to 100 and 125% RDF. This was particularly attributed to higher cost of fertilizers at higher doses especially with WSF.

In first crop both NF and WSF were found to be equally superior at 75% fertigation dose registering the highest benefit cost ratio of 2.54 and 2.53 respectively. In second and third crops, NF has outweighed the WSF in registering highest B: C ratio of 1.92 and 2.36 at 125% dose (II crop) and 75% dose (III crop) as shown in Table 7.

The overall assessment showed that NF was superior to WSF. Fertigation at 75% dose has resulted equivalent income per rupee invested with that of 100 and 125% doses. This trend of results is mainly attributed to the fact that the WSF are costlier than NF at higher doses, hence lower B: C ratio in spite of highest gross income obtained. In the present investigation the drip fertigation with NF at 75% fertigation dose + drip irrigation at 100% IRc is outstanding to achieve higher benefit cost ratio of 1.92, 1.82 and 2.36 in Ist, IInd and III crops respectively.

Hence considering the above situations, a Muscat grape grower can get higher income per rupee invested by adopting drip fertigation system with proper choice of fertilizer forms and schedule (Urea + Phosphoric acid + White Muriate of Potash) at 75% dose of recommended level while drip irrigation is scheduled at 100% IRc.

Table 7. Cost benefit analysis under drip fertigation in Muscat grapes
(Analyse coûts-avantages sous le fertigation d'égouttement en raisins de Muscat)

	Benefit cost ratio					
	Fertigation with Water Soluble Fertilizers			Fertigation with Normal Fertilizers		
	125%	100%	75%	125%	100%	75%
I Crop	2.12	2.32	2.53	2.39	2.50	2.54
II Crop	1.70	1.72	1.72	1.92	1.89	1.82
III Crop	1.88	2.00	2.16	2.16	2.27	2.36
Mean	1.90	2.02	2.14	2.15	2.22	2.24
Overall mean	2.02			2.21		

An analysis was made to assess the possible impact due to adoption of recommended technology from this study, drip irrigation at 100% computed irrigation requirement (IRc) and fertigation with NF (Urea + Phosphoric acid + Muriate of potash for N, P and K sources) at 75 % RDF in Tamil Nadu State in terms of overall monetary returns and illustrated in Table 8. by adoption of drip irrigation in the entire cultivated area of 2630 hectares under grapes in Tamil Nadu, there is a possibility of saving irrigation water upto 42080 ha cm (43 % water savings over conventional irrigation) corresponding to 0.421 million cubic meters. With this saving of irrigation water, an additional area of 1137.3 ha could be brought under drip irrigation. Due to the yield increase by adoption of the above technology 12827 tonnes of Muscat grapes could be additionally produced in the State with monetary value of 513 million rupees (11.40 million US$). Further the yield from the additional area could be 24634 tonnes of grapes corresponding to a return of 985.35 million rupees (21.90 million US$).

Table 8. Impact of adoption of recommended technology (from the project results) in Muscat grapes in Tamil Nadu State (Impact off adoption off recommended technology (from the project results) in Muscatel bunches in Tamil Nadu State)

Sl. No	Particulars	Conventional *	Drip Fertigation	Total Savings	In value	
					Rs. In Million	Million US $ (Rs.45/$)
1	Water requirement	530 mm	370 mm	160 mm	-	-
2	Total Water saving (43% compared to conventional)	-	42080 ha cm	0.421 million cubic metres	-	-
3	Additional area coverage due to water saving under drip	-	1137.3 ha	-	-	-
4	Yield increase from the existing area (2630 ha.)	-	12827 tonnes	-	513.06	11.40
5	Yield from additional area	-	24634 tonnes	-	985.35	21.90
6	Gross Additional income due to drip irrigation and fertigation	-	-	-	1498.41	33.30
7	Saving in fertilizer cost @ Rs15000 /ha due to fertigation at 75% dose with NF	Rs.65000 / ha	Rs.50000/ ha	-	39.45	0.88
8	Increased price due to better quality @Rs./ kg	Rs.40/kg	Rs.45/kg	-	187.20	4.16
9	Saving in energy (Electricity KWH/ha.) @Rs.5/per KWH/ha=Rs.7386/ha.				19.41	0.43
10	Overall Monetary returns in Tamil Nadu State	**-**	**-**	**-**	1744.07	38.77

* Data taken for comparison as reported in the literature and the current farmers practice

Hence, the gross additional revenue in Tamil Nadu State due to adoption of drip irrigation and fertigation in 2630 ha + 1137.3 ha under drip would be 1498.41 million rupees (33.30 million US $). There is also a reduction in the cost of fertilizers (up to 25%) with NF at 75% RDF at the rate of Rs.15000 per ha which would result a saving of 39.45 million rupees (0.88 million US $). Due to adoption of above technology, the increased market price at the rate of Rs.5/kg due to better fruit quality amounts to 187.2 million rupees (4.16 million US$). The energy saving under drip irrigation compared with flood irrigation was 1476 KWH per hectare in grapes as reported by Narayanamoorthy (1996). Taking into account the total cultivated area of grapes in TN, a sum of 19.41 million rupees (0.43 million US $) could be saved in Tamil Nadu State due to less pumping hours under drip irrigation in grapes. Considering this vital issue of saving electricity, subsidy for drip system is distributed by Electricity Board in Gujarat State (India) to the growers using drip irrigation. The saving in electricity (free for irrigation in some states in India) is being diverted to other demands like industry and domestic sectors in Gujarat State. Apart from the possible direct beneftits due to adoption of drip fertigation in Muscat grapes, indirect benefits also could be accrued like less ground water pollution (lesser NO_3 content) due to lesser inorganic fertilizers usage at 75% fertilizer dose by fertigation.
Thus the overall monetary returns that could be realized due to the adoption of the best practice from this study in Tamil Nadu State (where Muscat grapes is primarily grown in India) would be 1744 million rupees (38.77 million US$).

SUMMARY AND RECOMMENDATIONS

In the present investigation optimum fertigation, drip irrigation levels and forms of fertilizers have been standardized. Drip fertigation is a superior technology for maximizing the fruit yield and quality in Muscat grapes. Highest gross income could be realized with WSF (of course with greater initial investment) followed by NF. However investment is also major criteria for a grape grower considering the escalating labour and input costs, hence the optimum drip fertigation dose and schedule would maximize the income per rupee invested. In this context, compared to Water Soluble Fertilizers for fertigation, Normal Fertilizers (Urea +Phosphoric acid + Muriate of Potash) at 75% recommended dose has produced outstanding benefit cost ratio ranging from 1.92 to 2.36 per rupee invested.
Thus in the present investigation drip fertigation with Normal fertilizers at 75% NPK recommended dose with drip irrigation at 100% computed irrigation requirement is the most promising and economically viable technology for maximizing the fruit yield, quality and benefit cost ratio for the Muscat grape grower in Tamil Nadu State.

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