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POINTED GOURD PRODUCTION IMPROVEMENT USING RICE STRAW MULCH

ASESH KUMAR GHORAI

WATER TECHNOLOGY CENTRE FOR EASTERN REGION
BHUBANESWAR - 751016
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FOREWORD

Availability of irrigation water in the dry months and costly chemical fertilisers are main resource crunches to the farmers which restricts choice of cropping patterns. Application of organic mulches have proved to conserve more soil moisture, increase crop yield, reduce weed population and maintain soil sustainability long back. Pointed gourd (Trichosanthes dioica L.) is a vegetable cash crop of eastern India which requires frequent irrigations and high chemical fertilisers. The crop is grown in summer season in uplands and diara lands in some parts of eastern India. This vegetable is used as a delicacy. Application of rice straw mulch @ 14 to 16 tonnes/ha has proved to improve the crop yield by 77 to 180 percent (Ist to 3rd year) over traditional cultivation without mulch at near recommended fertiliser dose. Application of mulch maintained more favourable soil moisture and thermal regime and reduced weed population significantly. Organic matter, available potassium and phosphorus were also increased due to decomposition of mulches.

This bulletin is an outcome of intensive research conducted by Dr. A.K. Ghorai during the year 1991 to 1994. I am sure the bulletin will help the research and development personnel involved in the production of pointed gourd.

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(Author)

CONTENTS

INTRODUCTION

Use of mulch for better crop growth and improvement of soil edaphic properties is well known. Pointed gourd (Trichosanthes dioica l. Photo - 1) is a perennial minor cucurbit of high economic value and market demand. The crop is grown in eastern part of the country in river beds and sandy loam soil of hot & humid area. The crop is used as delicacy in this part of this country. The fruits have high keeping quality and thus useful in long transit. The fruits contain 92 percent moisture, 2 percent protein, 0.3 percent fat, 3 percent fibre, 2.2 percent carbohydrate, 153 mg carotene/100 g edible fruit, 30 mg Ca/100 mg edible fruit, 29 mg vitamin C/100 g of edible fruit. Rice straw can be used to improve soil environment, moisture conservation in hot summer, weed control and increase of fruit production.

Apart from the beneficial effect of mulching, for the ever increasing farm input prices it is essential to introduce such cropping patterns and locally available inputs that may bring substantial output value for farmer's benefit and maintain sustainability.

POTENTIALITIESAND LIMITATIONS

1. The crop yields 59 quintals of fruits/ha with optimum irrigation and mulching in the 1st year of cultivation. Ratoon crop for second and third years can yield as high as 76 quintals of tender fruits/ ha with mulching. Under best management situation 130 quintals of fruits can be harvested from third year ratoon crop. The yield sharply declines on fourth year.

2. Pointed gourd crop is an assured cash crop which responds well to irrigation, mulch and fertilizer.

3. The crop is least infected due to pest and diseases and highly responsive to straw mulch application. The fruits have high keeping quality and ratoon crop can be retained upto two years successively.

4. The crop is highly susceptible to waterlogging, frost, high soil and air temperature and heavy rainfall during.

PRODUCTION PACKAGES

Soil :

Well drained, fertile sandy loam soil is better for the crop growth. The crop is highly susceptible to water logging. The crop is sensitive to lower pH (below 5.5). The crop grows well in the river beds and alluvial soil where the shallow water table helps the tap roots of this perennial cucurbit.

Temperature :

The crop is a summer crop and also grows well in Kharif season where the rainfall is scanty. It is highly susceptible to high rainfall. The optimum temperature is 25-30 ^{0} C. The crop is sensiitive to temperature below 50c. The optimum soil temperature at 30 cm deep soil layer is 32 - 330C.

Land Preparation and Planting Method :

The crop is grown in bed and furrow system (Photo 2a and 2b) at a spacing of 6'x3'. The bed should be so designed that the excess water is easily drained. The roots are planted in 1' x 1' x 1' pits (filled with well rotten F.Y.M.) in 9:1 (female:male) ratio and 3 - 4 roots/pit. The roots after planting should be covered with loose straw for maintenance of soil moisture and temperature for easy germination. During germination the irrigation should be only to maintain field capacity of the soil. Pot irrigation is adequate. For ratooning, the mother and young plants in situ are clippped off at 12 - 15 cm vine length from base in the month of December where from the new vines generates for next crop.

Sowing Time :

The new roots are planted in the month of December-January (depending on the temperature) and the ratooning is practised from 15th December to end of January.

Variety :

Local clones are still grown in the cultivated areas.

Root Treatment :

The roots suckers should be soaked with Dithane M - 45 @ 2.5 g/litre of water to avoid fungal attack.

Straw Mulch Application :

Straw mulch is applied when the sprouted twigs are 15-20 cm long approximately (20 - 30 days after planting roots). The soil should be treated with some chemicals to avoid white ant (termite) attack. For experiment B.H.C. was applied @ 25 kg/ha.

Irrigation Application :

Irrigation at IW/CPE = 1.55 or 9-10 days interval is suitable for sandy soil. The irrigation schedule will vary according to texture of soil.

Harvesting :

The tender fruits are harvested when the seeds inside the fruits are still soft. Harvesting continues for a long period from January to October (depending on prevailing temperature). The fruit yield reduces in the heavy rainfall period during rainy season.

Fertilizer Application :

The crop responds well to fertilizer application. Application of N : P_2O_5:K_2O @ 90:60:60 kg/ha has been proved to bring out the potential yield. A two third of total nitrogen fertilizer is applied before mulching (20 - 30 DAS) and 1/3rd N is applied during September to October when rainfall ceases.

EXPERIMENTAL FINDINGS

Experiments have been conducted at Deras Research Farm (Khurda), Mendhasal, Orissa in the years on 1991, 1992, 1993 and 1994. The soil is acidic in nature (pH 5.61) having a bulk density of

1.53 g/cc. The experiment were laid out in split plot design where main plots were allotted with irrigation treatments and the sub plots were allotted with rice straw mulches. The rice straw mulch were applied at 2 different doses in 1991 i.e. no mulch and mulch @ 15 tonnes/ha.

On subsequent years mulches were applied @ 8, 12, 16, and 20 tonnes/ha alongwith a control treatment of no mulch. The detailed irrigation schedules are shown in Table 1 (a), 1 (b), 1 (c) and 1 (d). The mulch plots were treated with B.H.C. 10% @ 25 kg/ha before spreading rice straw on the plots to avoid white ant attack.

Roots of a local clone were planted on raised ridges on pits (size 1' x 1' x 1)' filled with well rotten FYM at a spacing of 6' x 3' distance. The fertiliser doses applied were 80:40:40 in 1991 and 90:60:60::N:P_2O_5:K_2O in subsequent years.

The available nitrogen, phosphorus and potassium were 225 kg, 12 kg and 125 kg/ha, respectively. Ratooning was practised on 2nd, 3rd and 4th years of cultivation.

Table 1 (a) : Detailed scheduling of irriigation for the years 1991.

Irrigation	Depth of each irrigation (cm)	Total number of irrigations applied	Total depth of irrigation applied (cm)
IW/CPE= Nil	nil	nil	nil
IW/CPE=1.5	7.5	18	135
IW/CPE=1.8	7.5	22	165
IW/CPE= 2.2	7.5	26	195
IW/CPE= 2.4	7.5	29	218

Table 1 (b) : Details scheduling of irrigation for the years 1993 and 1994.

Irrigation	Depth of each irrigation(cm)		Total number of irrigations applied		Total depth of irrigation applied (cm)	
	1993	1994	1993	1994	1993	1994
IW/CPE = 0.5	7.5	7.5	05	06	37.5	45.0
IW/CPE = 1.0	7.5	7.5	08	09	60.0	67.5
IW/CPE = 1.5	7.5	7.5	11	10	82.5	75.0
IW/CPE = 2.0	7.5	7.5	12	14	90.0	105.0

EFFECT OF IRRIGATION

Crop Growth and Yield :

Due to shallow water table condition the irrigation levels did not show any significant impact on the yield and yield components of the crop. In 1991 irrigation at IW/CPE 1.8 in combination with mulch @ 15 tonnes/ha recorded highest yield (Table 2b). In 1993 and 1994 irrigation at IW/CPE= 1.5 gave better yields over others, Table 2 (d) and 2(e). Thirty to 53 cm irrigation water can be saved if mulch is applied @ 15 to 16 tonnes/ha in combination with irrigation at IW/CPE = 1.5 to 1.8 over irrigating the crop at IW/CPE = 2.0 to 2.4, which gives satisfactory high yield, (Table 1a).

Table 2(a) : Yield and yield components of pointed gourd as influenced by different levels of irrigation and mulch, 1991.

Treatment	Total fruits/ha Nos.	Total weight of fruits kg/ha	Length of fruits (cm)	Width of fruits (cm)	Average weight of fruits (g)
Irrigation	—	—	—	—	—
IW/CPE=Nil	69141	2518	7.37	10.47	29.56
IW/CPE=1.5	97153	3584	7.56	11.23	31.17
IW/CPE=1.8	106462	4484	7.48	11.84	30.98
IW/CPE=2.2	89646	2916	7.46	11.65	28.39
IW/CPE=2.4	85217	2567	7.40	11.48	28.28
C.D. at 5%	NS	NS	NS	0.772	NS
Mulch	—	—	—	—	—
000 Kg/ha	62315	2229	7.29	11.01	28.09
15000 Kg/ha	112723	4199	7.62	11.67	31.24
C.D. at 5%	17122	627	0.154	0.28	NS
C.D. at 1%	24354	892	—	—	

Table 2 (b) : Interaction effect of irrigation and mulch on the yield of pointed gourd, 1991.

Treatments		Irrigation schedule			
	IW/CPE=	IW/CPE=	IW/CPE=	IW/CPE=	IW/CPE=
Mulch. Kg/ha	00	1.5	1.8	2.2	2.4
Fruit yield (kg/ha)					
000	2395	2421	3097	2063	1170
15000	2641	4747	5871	3769	3965
—	IXM	—	MXI	—	
S.Em ±	—	629	—	952	—
C.D. at 5%	—	NS	—	NS	—

Table 2 (c): Yield and yield components of pointed gourd as influenced by different doses of straw mulch (kg/h), 1992.

Doses of straw mulch (kg/ha)	Yield of pointed gourd (kg/ha)	Fruits/ ha	Average weight (g)	Thick (cm)	Length (cm)
0	1910	62896	29	11.09	8.89
8000	2671	107913	31	11.31	9.13
12000	2814	149577	31	11.35	8.98
16000	3390	110837	32	11.37	9.20
20000	2617	80379	34	11.29	9.23

All the years (except 1994) crop yield showed a quadratic functional relationship with the application of irrigation. The optimum irrigation dose was IW/CPE= 1.55for 1991 and IW/CPE= 1.56 and 1.16 for 1993 and 1994, respectively. In 1994, a combination of irrigation at IW/CPE= 1.5 and mulch @ 16 tonnes/ha saved thirty cm irrigation water over next irrigation schedule at IW/CPE = 2.00 with mulch @ 16 tonnes/ha where yield was maximised. Yield of crop for (1993 and 1994) under different IW/CPE is shown in Fig.1.

$$Y\ (1991) = 2490 + 2740.01\ X - 1121\ X^2,\ R^2 = 0.72 \quad (1)$$

$$Y\ (1993) = 977.49 + 4977.60\ X - 1592\ X^2,\ R^2 = 0.84 \quad (2)$$

$$Y\ (1994) = 746.5 + 2117\ X - 916\ X^2,\ R^2 = 0.17 \quad (3)$$

where Y is the yield of pointed gourd in kg/ha and X is the doses of irrigation in IW/CPE. The same type of result were also recorded on number of fruits/ha (Fig.2).

$$Y_{FN}(1991) = 68872 + 47365\ X - 16838\ X^2,\ R^2 + 0.90 \quad (4)$$

$$Y_{FN}(1993) = 27759 + 166099\ X - 55970\ X^2,\ R^2 = 0.74 \quad (5)$$

$$Y_{FN}(1994) = 46667 + 275086\ X - 124119\ X^2,\ R^2 = 0.98 \quad (6)$$

here Y_{FN} is the number of fruits per hectare and X is the doses of irrigation in IW/CPE.

The average length, average weight and thickness of fruits were unaffected due to varying irrigation levels.

EFFECT OF MULCH

Yield and Yield Component :

Crop Yield :

The application of straw mulch recorded a significant impact on the yields and yield components of pointed gourd. In 1991, 1992, 1993 and 1994 application of straw mulch increased yield of pointed gourd significantly over no mulch. Application of rice straw mulch @ 15-16 tonnes/ha increased fruit yield by 88 percent, 77 percent, 163 percent and 323 percent over no mulch on the years 1991, 1992, 1993 and 1994, respectively. The crop yield drastically reduced on 1994.

The increased crop yield were again due to higher total fruits/ha, heavier and healthier individual fruit production by mulching over no mulching. Increased crop yield have also been confirmed by Johnson & Davis (1972), Chatterjee & Sen (1977). Medcalf (195) reported 72 percent increase in coffee yield due to mulching in Brazil. The detailed yield data is shown in Table 2(a), 2(b), 2(c), 2(d), 2(e), 2(f). The yield and mulch relation for different years is shown in Fig.3.

Reduction of yield due to higher mulching doses may be due to excess water held in soil leading to anaerobic condition and nitrogen deficiency through leaching as quoted by Gordon Wrigley (1981) in sugarcane in Mauritius.

Gordon Wrigley (1981) in tropical agriculture had reported that in Northern Nigeria mulched plots produced 348 kg threshed sunflower seeds/ha as compared to 95 kg without mulch.

Table 2(d) : Effect of mulch and irrigation on the yield and yield components of pointed gourd, 1993.

Treatments Irrigation	Fruit yield kg/ha	Number of fruits Nos.	Av. weight (g)	Av. length (cm)	Av. thick-ness (cm)	Plants/ ha
IW/CPE=0.5	3204	102217	32	6.5	11.9	37963
IW/CPE=1.0	3956	121686	30.4	6.5	11.7	35331
IW/CPE=1.5	5269	167178	29.80	6.5	11.8	42520
IW/CPE=2.0	4429	130677	30.50	6.6	11.8	36526
S.Em ±	1020.6	35047	1.34	0.09	0.13	8735
C.D. at 5%	NS	NS	NS	NS	NS	NS
C.D. at 1%	NS	NS	NS	NS	NS	NS
C.V. %	66.34	73.6	11.94	3.81	3.03	62.8
Mulch (kg/ha)	—	—	—	—	—	—
000	2034	66033	29.08	6.21	11.56	1943
8000	3675	113852	30.80	6.45	11.86	41484
12000	5247	159965	30.60	6.71	11.89	42459
16000	5363	162707	31.01	6.58	11.80	43160
20000	4752	149641	31.85	6.69	11.85	43891
S.Em ±	817.1	22383	0.81	0.09	0.108	7019
C.D. at 5%	1665	45617	1.65	0.18	0.22	14341
C.D. at 1%	2239.6	61351	NS	0.251	NS	19367
C.V. %	47.49	42.03	6.47	3.40	2.20	45.15

Yield of pointed gourd showed second order functional relation with the application of straw mulch. The best fit regression equations between yield and straw mulch are shown here.

$$F_{FY}\,(1992) = 1860 + 161.23\,X - 5.694\,X^2,\ R^2 = 0.78 \quad (7)$$

$$F_{FY}\,(1993) = 1902.94 + 385.08\,X - 11.58\,X^2,\ R^2 = 0.92^* \quad (8)$$

$$F_{FY}\,(1994) = 536.51 + 161.56\,X - 3.88\,X^2,\ R^2 = 0.96 \quad (9)$$

here F_{FY} is the fruit yield and X is the doses of straw mulch in tonnes/ha. The optimum doses for straw mulches or 1992, 1993 were 14 and 16.6 tonnes/ha respectively. The fruit yields were at par due to mulching @ 12 and 16 tonnes/ha in 1993.

Fruit Numbers/ha Versus Mulch

Number of fruit production/ha in the experimental years showed 2nd order functional relation to the application of straw mulch. The fruit number due to mulching @ 15 (1991) and 16 tonnes/ha (1992, 1993, 1994) were increased by 81 percent, 76 percent, 146 percent and 300 percent, respectively. The pictoral representation is shown in Fig.4.

$$F_{FY} (1992) = 59756.52 + 1286 X - 587.3 X^2, R^2 = 0.83 \quad (10)$$

$$F_{FY} (1993) = 62475.6 + 10901 X - 313.25 X^2, R^2 = 0.93^* \quad (11)$$

$$F_{FY} (1994) = 21417 + 6028 X - 154.36 X^2, R^2 = 0.84 \quad (12)$$

here F_{FY} is the number of fruits produced per hetare and X is the doses of straw mulch in tonnes/ha.

Average Weight (g)

The average weight of fruits were increased by application straw mulch (Fig.5). The average fruit weight due to mulching @ 15 (1991) and 16 tonnes/ha (1992, 1993, 1994) were increased by 11 percent, 10.34 percent, 6.6 percent and 15.87 percent, respectively. The fruit sizes were reduced on the 4th year. The linear response is shown here.

$$F_{AW} (1992) = 29.01 + 0.22 X, R^2 = 0956 \quad (13)$$

$$F_{AW} (1993) = 29.28 + 0.1239 X, R^2 = 0.89 \quad (14)$$

$$F_{AW} (1994) = 23.80 + 0.2229 X, R^2 = 0.84 \quad (15)$$

here F_{AW} is the average weight of fruits in (g) and X is the doses of straw mulch in tonnes/ha.

Average Fruit Length (cm)

The average fruit length were also influenced due to different levels of mulches (Fig.6). The average fruit length due to mulching @ 15 (1991) and 16 tonnes/ha (1992, 1993, 1994) were increased by 4.5 percent, 3.36 percent, 5.95 percent and 12 percent, respectively. The fruits weight were increased on 2nd year and declined there after. The functional relations are

$$F_{AL} (1992) = 8.907 + 0.0159 X R^2 = 0.70 \quad (16)$$

$$F_{AL} (1993) = 6.20. + 0.0478 X - 0.00122 X^2, R^2 = 0.87 \quad (17)$$

$$F_{AL} (1994) = 5.747 + 0.039 X, R^2 = 0.81^* \quad (18)$$

where F_{AL} is the average length of fruits in cm and X is the doses of straw mulch applied to the crop in tonnes/ha.

Average Thickness (cm)

The thickness of fruits (maximum girth at the central position) were also influenced due to straw mulching. The average fruit thickness due to mulching @ 15 (1991) and 16 tonnes/ha (1992, 1993, 1994) were increased by 5.99 percent 2.46 percent, 2.07 percent and 4.8 percent, respectively. The functional relations are shown here.

$$F_{AT}(1992) = 11.09 + 0.043\ X - 0.00149\ X^2,\ R^2 = 0.99 \quad (19)$$

$$F_{AT}(1993) = 11.57 + 0.045\ X - 0.0016\ X^2,\ R^2 = 0.88 \quad (20)$$

$$F_{AT}(1994) = 10.69 + 0.065\ X - 0.00191\ X^2,\ R^2 = 0.79 \quad (21)$$

here F_{AT} is the thickness of fruits in cm and X is the doses of mulch in tonnes/ha.

Table 2(e) : Effect of mulch and irrigation levels on the yield of pointed gourd (kg/ha), 1993

Treatments	Doses of mulch tonnes/ha					
Irrigation	00	08	12	16	18	20
	Yield of fruits (Kg/ha)					
IW/CPE=0.5	2234	3243	3920	2566	4058	3204
IW/CPE=1.0	2464	2810	4237	5943	4323	3955
IW/CPE=1.5	1309	4800	6382	7619*	6233	5269
IW/CPE=2.0	2128	3846	6451	5324	4394	4429
—	I*M		—	M*I		—
S.Em±	1634		—	1630		—
C.D. at 5 %	NS		—	NS		—

Table 2(f) : Yield and yield components of pointed gourd as influenced by different doses of mulch and irrigation, 1994.

Treatments / Irrigation	Yield kg/ha	Total Fruit (nos.)	Average fruit wt./ ha (g)	fruits length (Av.) (g)	Max. girth (Av.) (cm)
IW/CPE=0.5	1818	62430	26.7	6.2	11.1
IW/CPE=1.0	1222	45483	26.9	6.1	11.2
IW/CPE=1.5	2587	96549	26.1	6.3	11.1
IW/CPE=2.0	1075	44447	25.5	6.1	11.0
S.Em.±	332.0	13537	0.73	0.11	0.085
C.D. at 5%	NS	NS	NS	NS	NS
C.V.(%)	76.71	84.25	10.77	6.93	—
Mulch (t/ha)	—	—	—	—	—
0	584	23955	22.86	5.61	10.66
8	1458	52925	27.39	6.30	11.27
12	1808	66604	26.56	6.25	11.08
16	2472	95889	26.49	6.29	11.18
20	2051	71760	28.19	6.49	11.30
S.Em ±	285.57	10151	0.76	0.108	0.115
C.D. at 5%	582	20617	1.54	0.219	0.234
C.D. at 1%	784	27824	2.08	0.296	0.425
C.V. (%)	59.04	56.51	10.05	6.00	3.61

Declining yield of pointed gourd is shown in Fig.7

Moisture Conservation By Mulching :

The soil moisture storage before and after irrigation were determined gravimetrically from the field soil. Straw mulch maintained/stored more moisture before and after irrigation application (Fig 8 and 9). As high as 39 percent more moisture was stored in 45 cm depth soil than traditional no mulch cultivation before irrigation (1993), Table 3(a). The moisture storage capacity was improved by 7-17 percent due to mulching 24 hours after irrigation (1993).

Table 3(a) : Seasonal average water stored in 45 cm depth of soil before and after irrigation 1993

Irrigation (IW/CPE=0.5)	Before irrigation (Cm)	Percent over no mulch	After irrigation(Cm)	Percent over no mulch
No mulch	6.60	—	9.32	—
8 t/ha	7.49	13.48	9.94	6.65
12 t/ha	7.57	14.70	10.16	9.01
16 t/ha	6.81	3.18	10.38	11.37
20 t/ha	7.36	11.52	10.05	7.83
Irrigation (IW/CPE=1)	—	—	—	—
No mulch	5.93	—	9.19	—
8 t/ha	6.66	12.31	9.00	—
12 t/ha	7.49	26.31	10.63	15.67
16 t/ha	7.84	32.21	9.99	11.8
20 t/ha	8.23	38.78	10.78	17.30
Irrigation IW/CPE=1.5	—	—	—	—
No mulch	6.81	—	9.11	—
8 t/h	7.45	9.39	9.26	1.65
12 t/ha	8.21	20.56	9.94	9.11
16 t/ha	8.29	21.73	9.92	8.89
20 t/ha	8.11	19.09	10.38	13.94
Irrigation IW/CPE = 2.0	—	—	—	—
No mulch	7.01	—	9.29	—
8 t/ha	7.86	12.13	9.92	6.78
12 t/ha	7.90	12.69	10.20	9.79
16 t/ha	8.05	14.84	10.27	10.55
20 t/ha	8.13	16.0	10.3	10.3

The linear functional relationship between the cm of water stored at 0 - 45 cm soil versus mulch application, before irrigation are shown below for 1993.

$$Y_{ws}(IW/CPE = 0.5) = 6.889 + 0.0237\ X,\ R^2 = 0.177 \quad (22)$$

$$Y_{ws}(IW/CPE = 1.0) = 5.89 + 0.0827\ X,\ R^2 = 0.98^{**} \quad (23)$$

$$Y_{ws}(IW/CPE = 1.5) = 6.94 + 0.074\ X,\ R^2 = 0.81^{*} \quad (24)$$

$$Y_{ws}(IW/CPE = 2.0) = 7.18 + 0.0542\ X,\ R^2 = 0.86 \quad (25)$$

where Y_{ws} is the cm of water stored at 0 - 45 cm soil depth before irrigation at different irrigation schedules and X is the doses of straw mulch in tonnes/ha.

The functional relation between the cm of water stored at 0 - 45 cm soil versus mulch application 24 hours after irrigation are shown below (1993).

$$Y_{ws}(IW/CPE = 0.5) = 9.487 + 0.0407\ X,\ R^2 = 0.69 \quad (26)$$

$$Y_{ws}(IW/CPE = 1.0) = 8.991 - 0.0827\ X,\ R^2 = 0.62 \quad (27)$$

$$Y_{ws}(IW/CPE = 1.5) = 9.00 + 0.064\ X,\ R^2 = 0.88^{*} \quad (28)$$

$$Y_{ws}(IW/CPE = 2.0) = 9.41 + 0.0519\ X,\ R^2 = 0.89^{*} \quad (29)$$

where Y_{ws} is the cm of water stored at 0 - 45 cm soil depth after irrigation at different irrigation schedules and X is the doses of straw mulch in tonnes/ha.

The soil moisture depletion were determined using the following formula for a particular irrigation interval.

$$D_i = \frac{(M_1 - M_2) \times B.D. \times d_i}{100}$$

D_i = Soil moisture depletion for particular depth (in cm)

M_1 and M_2 are the percentage of soil moisture before and after irrigation.

B.D. is the bulk density of soil in g/cc

d_i is the depth of root zone in cm

Table 4(b) : Total seasonal water loss due to depletion of moisture under different levels of irrigation and mulch, 1993.

Treatments	Straw mulch in tonnes per ha					
Irrigation	00	8	12	16	20	Mean
	Depth of water (cm)					
IW/CPE =0.5	13.6	7.56	9.98	13.8	6.2	10.2
IW/CPE =1.0	23.4	15.7	18.4	14.2	14.8	17.3
IW/CPE =1.5	17.4	16.0	14.8	15.7	20.0	16.8
IW/CPE =2.0	20.2	17.4	18.0	17.7	16.7	17.9
Mean	18.7	14.2	15.3	15.4	14.4	—

The soil moisture depletion (excluding ground water contribution and effective rainfall) increased linearly with the higher irrigation frequency and decreased with the higher doses of mulching. The functional relations are represented below for 1993.

$$Y(I) = 9.889 + 4.5199\ X_i,\ R^2 = 0.66 \quad (30)$$

$$Y(M) = 17.59 - 0.177\ X_m,\ R^2 = 0.56 \quad (31)$$

where Y(I) and Y(M) are the total depth water depleted in cm and X_i and X_m are the doses of irrigation (IW/CPE) and straw mulches in tonnes/ha.

Soil Temperature Moderation Using Mulch :

The soil temperature was greatly moderated due to straw mulching. The mulch application kept the surface and 30 cm deep soil much cooler over bare cultivation. The mulch application kept the soil at optimum temperature regime. In the morning, surface and 30 cm deep soil layer remain 4 and 3°C cooler due to mulching over no mulching. At 2.00 p.m. the surface and 30 cm deep soil layer remains 10 - 12°C and 5 - 6°c cooler (Fig 10 and 11) due to mulching. The best fit equations are shown for surface and 30 cm deep soil layer (Table 4a, 4b, 4c, 4d).

$$T_1 = 39.36 - 0.401\ X_1,\ R^2 = 0.76 \quad (32)$$

$$T_2 = 36.68 - 0.274\ X_2,\ R^2 = 0.76 \quad (33)$$

where T_1 and T_2 are the surface and 30 cm deep soil temperatures in ^{0}C and X_1 X_2 are doses of straw mulch in tonnes/ha. The reduction in diurnal range of soil temperature to 1.5 - 3^{0}C from 12^{0}C had been reported by Gilbert (1945) due to mulching in Tanzania at a depth of 55 mm.

Table 4 (a): Effect of irrigation and straw mulch on the surface soil temperature (^{0}C) at 9 - 10 a.m., May, 1993.

Mulch	straw mulch in tonnes per ha.					
Irrigation	00	8.0	12.0	16.0	20.0	Mean
	Temperature in ^{0}C					
IW/CPE=0.5	33.4	30.2	30.5	30.4	30.6	31.0
IW/CPE=1.0	33.9	30.2	30.3	30.0	30.8	31.0
IW/CPE=1.5	34.5	30.6	30.8	30.5	30.4	31.3
IW/CPE=2.0	34.7	30.2	30.0	30.2	30.1	31.0
Mean	34.1	30.3	30.4	30.3	30.5	——

Table 4(b) : Effect of irrigation and straw mulch on surface soil temperature (^{0}C) at 2.00 p.m. May, 1993.

Mulch	Straw mulch in tonnes per ha					
Irrigation	00	08	12	16	20	Mean
	Temperature in ^{0}C					
IW/CPE =0.5	44.2	35.3	34.6	34.8	33.6	36.5
IW/CPe =1.0	41.0	34.4	33.4	32.8	32.9	34.9
IW/CPE =1.5	39.3	33.3	32.9	32.3	33.1	34.2
IW/CPE =2.0	40.0	32.7	32.5	32.2	31.9	33.9
Mean	41.2	33.9	33.4	33.0	32.9	—

Table 4c : Effect of mulch and irrigation levels on the 30 cm deep soil layer temperature at 9 - 10 a.m. (May, 1993).

Mulch	Straw mulch in tonnes /ha					
Irrigation	00	08	12	16	20	Mean
	Temperature in ^{0}C					
IW/CPE=0.5	33.5	31.3	31.1	30.8	30.4	31.4
IW/CPE=1.0	33.3	30.9	30.1	30.6	30.7	31.2
IW/CPE=1.5	32.7	30.8	30.5	30.4	30.5	30.9
IW/CPE=2.0	33.3	30.74	30.6	30.6	30.3	31.1
Mean	33.2	30.93	30.7	30.6	30.5	—

Table 4(d) : Effect of straw mulch and irrigation levels on the 30 cm deep soil layer temperature at 2.00 p.m. (May), 1993.

Mulch	Doses of straw mulch, tonnes/ha					
Irrigation	00	08	12	16	20	Mean
	Temperature in ^{0}C					
IW/CPE=0.5	38.9	33..6	33.4	32.8	32.5	34.2
IW/CPE=1.0	37.8	33.1	32.6	32.2	32.6	33.6
IW/CPE=1.5	37.4	32.9	32.3	31.9	32.3	33.37
IW/CPE=2.0	37.5	32.4	32.3	31.9	31.7	33.2
Mean	37.9	32.9	32.6	32.2	32.3	—

Weed Control and Straw Mulch :

Controlling weed is a severe problem in dry as well as wet months in this subtropical humid region which require frequent weeding operation that increases both cost of cultivation as well as reduces the fertility status of soil by removing nutrients applied for the crops. Weed dry weight were measured in monthly interval to compare the weed controlling ability of mulch. The weed population was sucessfully

reduced due to application of straw mulch both on dry and wet months (Fig 12, Photo 2a and 2b). The weed control was mainly due to smothering effect on weed (Table 5a, 5b and 5c). Main weed species were *Cyperus rotundus, Cynodon dactylon, Digittaria species, Echinochloa colonum, Eclipta alba etc.*

Table 5(a): The relative weed growth due to different doses of straw mulch 1992.

Straw mulch (kg/ha)	Dry weight of weed (kg/ha) June 92	Dry weight of weed (kg/ha) July 92	Dry weight of weed (kg/ha) Aug 92	Dry weight of weed (kg/ha) Sept 92
00	1046	1052	1256	1301
8000	650	635	918	1062
12000	417	598	872	1272
16000	462	649	863	853
20000	389	577	612	966

Table 5(b) : Weed growth as influenced by different levels of irrigation and straw mulch (kg/ha) 1993.

Treatments	Dry weight of weeds (kg/ha)						
Irrigation	April	May	June	July	Aug.	Sept.	Oct.
IW/CPE=0.5	133	226	237	1249	871	1646	1892
IW/CPE=1.0	175	241	362	1267	952	1506	1614
IW/CPE=1.5	230	356	414	844	847	1645	1441
IW/CPE=2.0	263	222	385	808	847	1663	1691
S.Em ±	15.57	34.40	25.06	278	150.6	105	10
C.D. at 5%	30.09	84.18	61.32	NS	NS	NS	253
C.D. at 1%	57.73	NS	92.90	NS	NS	NS	NS
C.V. %	21.31	36.06	19.64	73.1	46.91	17.77	17.0
Mulch (kg/ha)	—	—	—	—	—	—	—
0	509	551	762	1634	1190	2223	2576
8000	159	293	396	593	982	1513	1593
12000	142	187	265	945	825	1442	1574
16000	84	211	165	917	786	1450	1421
20000	106	123	159	1123	615	1447	113
S.Em ±	21.73	52.89	45.26	282	121	113	162
C.D. at 5%	44.29	107.79	92.24	575	248	230	33
C.D. at 1%	59.58	144.98	124.0	NS	333	310	445
C.V.%	26.60	49.59	31.72	66.3	33.86	17.14	24.0

The weed control aspects of mulching had been reported by many workers. The said phenomena has also been reported in annual report, IITA (Nigeria) in 1976.

Table 5(c) : Weed growth on pointed gourd field as influenced by different doses of mulch and irrigation, 1994.

Treatments	Weed dry weight (kg/ha) (oven dry at 76 °C)				
Irrigation	March	April	June	July	Nov.
IW/CPE=0.5	400	903	477	1011	2408
IW/CPE=1.0	343	1000	713	1155	2632
IW/CPE=1.5	428	851	435	1046	2061
IW/CPE=2.0	253	1349	573	946	2557
S.Em.±	66.47	65.27	103.44	98.30	271.8
C.D. at 5%	NS	159.71	NS	NS	NS
C.V. (%)	72.27	24.64	72.94	36.62	43.59
Mulch (t/ha)	—	—	—	—	—
0	256	1791	741	1604	3028
8	350	1117	652	1011	2429
12	375	896	493	912	2287
16	417	789	520	921	2045
20	384	537	340	749	2283
S.Em.±	42.86	101.13	53.58	114.42	143.7
C.D. at 5%	NS	205.39	109.19	233.18	293.0
C.D. at 1%	NS	277	146.86	314	394.1
C.V. (%)	41.68	34.16	37.79	38.13	20.63

The functional relations between weed dry matter and straw mulch are shown here

$$Y_{WD}\,(1992, \text{July}) = 945.45 - 21.72\,X,\ R^2 = 0.715 \qquad (34)$$

$$Y_{WD}(1993, Aug) = 1192.97 - 27.979\ X,\ R^2 = 0.98^{**} \quad (35)$$

$$Y_{WD}(1994, July) = 762.18 - 19.01\ X,\ R^2 = 0.90 \quad (36)$$

where Y_{WD} is the weed dry weight in kg/ha and X is doses of straw mulch in tonnes/ha.

Chemical Properties Of Soil As Influenced By Mulches.

Soil pH and Straw Mulch :

The crop is highly sensitive to acidic (pH less 5.5). Hence study was made to see whether the application of straw mulch had affected the soil reaction or not. The application of straw mulch has shown a slight improvement (non significant) in the rise of pH of soil (Table 6a and 6b, Fig 14). The functional relation between pH and doses of straw mulch is shown here.

$$Y_{PH}(1993) = 5.43 + 0.0056\ X,\ R^2 = 0.82^{*} \quad (37)$$

$$Y_{PH}(1994) = 5.358 + 0.015\ X,\ R^2 = 0.96 \quad (38)$$

where Y_{PH} was the pH of soil and X was the straw mulch doses in tonnes/ha. Reduction of soil acidity had been reported by Gordon Wrigley in Tropical agriculture the development and production.

Redox Potential (mv) Versus Mulch and Irrigation

The redox potential of soil were inversely related to the doses of straw mulches applied to the soil. The functional relation are shown here.

$$Y_{RP}(1993) = 89.57 - 0.38\ X,\ R^2 = 0.83^{*} \quad (39)$$

$$Y_{RP}(1994) = 97.02 - 1.052\ X,\ R^2 = 0.98 \quad (40)$$

where Y_{RP} is the redox potential in mv and X is the doses of straw mulch in tonnes/ha. The irrigation application had also negative impact on the redox potential of the soil.

$$Y_{RP}(1993) = 92.34 - 5.62\ X,\ R^2 = 0.72 \quad (41)$$

$$Y_{RP}(1994) = 96.70 - 9.22\ X,\ R^2 = 0.98 \quad (42)$$

here Y_{RP} represents the redox potential in mv and X represents the doses of irrigation on IW/CPE.

The Organic Matter and Straw Mulch

The organic matter content of soil was improved due to mulching (1993, Fig 13). The said result is clear from table 6(a) and 6(b). The first order functional relation is represented here.

$$Y_{OM}\,(1993) = 0.3559 + 0.0068\ X,\ R^2 = 0.92^* \qquad (43)$$

where Y_{OM} is the organic matter content of soil and X is the doses of straw mulch in tonnes/ha. Increase in organic matter content of soil had been reported by Robinson in 1951.

Electrical Conductivity of Soil and Straw Mulch.

The electrical conductivity of soil were increased due to application of straw mulch, table 6(b).

$$Y_{EC}\,(1994) = 56.52 + 1.000\ X,\ R^2 = 62.36 \qquad (44)$$

where Y is the electrical conductivity in µmhos/cm at 25°C and X is the doses of straw mulch in tonnes/ha.

Available Nitrogen

Available nitrogen were not affected due to application of straw mulch (Table - 6d, fig 15). Reduction of available nitrogen in soil had been reported by Medcalf in 1956.

Soil Available Potassium & Straw Mulch

The application of straw mulch increased the available potassium content of soil after the harvest of the crop. The functional relations are shown here.

$$Y_K\,(1992) = 103.89 + 7.95\ X,\ R^2 = 0.84^* \qquad (45)$$

$$Y_K(1993) = 109.27 + 5.547\ X,\ R^2 = 0.92 \qquad (46)$$

where Y_K is the available potassium content of soil in kg/ha and X is the doses of straw mulch in tonnes/ha. Addition of 1250 kg potassium had been reported by Robinson and Chenery (1958) due to application of 25 tonnes of elephant grass/ha as mulch. Medcalf 1956 reported increased availability of potassium due to mulching. Mehlich (1966) suggested the use of maize stover as a source of potash for mulching in coffee.

Table 6(a) : Some chemical characteristics of soil as influenced by different levels of irrigation and mulch, 1993.

Treatments Irrigation	Oxidisable C'(%)	Organic matter (%)	pH	Redox potential (mv)	Bulk density (g/cc)
IW/CPE=0.5	0.20	0.4	5.4	89.7	1.5
IW/CPE=1.0	0.20	0.4	5.4	91.3	1.5
IW/CPE=1.5	0.30	0.5	5.7	74.3	1.5
IW/CPE=2.0	0.30	0.4	5.5	86.0	1.5
S.Em ±	—	0.017	0.072	3.822	-
C.D. at 5%	NS	0.041	0.178	14.17	NS
C.D. at 1%	NS	NS	NS	NS	NS
C.V. (%)	19.53	11.69	3.68	12.27	4.48
Mulch (kg/ha)	—	—	—	—	—
0	0.21	0.36	5.42	90.17	1.51
8000	0.25	0.42	5.50	85.33	1.52
12000	0.24	0.42	5.48	86.17	1.52
16000	0.29	0.45	5.54	81.83	1.51
20000	0.30	0.51	5.53	83.08	1.53
S.Em ±	0.0165	0.0223	0.071	4.37	—
C.D. at 5%	0.0336	0.0466	NS	NS	NS
C.D. at 1%	0.0452	0.0611	NS	NS	NS
C.V. (%)	13.87	12.40	3.16	12.55	3.04

Soil Available Phosphorus and Straw Mulch

The available phosphorus of soil was improved due to application of straw mulch in soil. This may be due to reduced activity of iron and aluminium in soil and less fixation of phosphorus by iron and aluminium. The increased availability of phosphorus had been reported by Medcalf (1956) due to

application of mulch. Brady (1990) reported that availability of phosphorus increases due to stable complexes of organic acids with iron and aluminium from added organic matter which reduces fixation. The first order functional relation is shown here.

$$Y_P\ (1993) = 12.43 + 0.2114\ X,\ R^2 = 0.86 \qquad (47)$$

where Y is the available phosphorus in kg/ha and X is the doses of straw mulch in tonnes/ha.

Table 6(b) : Some chemical properties of pointed gourd field soil as influenced by different doses of mulch and irrigation, 1994.

Treatments Irrigation	pH	Redox-potential (mv)	Electrical conductivity µmhos/cm
IW/CPE=0.5	5.4	92.0	74.1
IW/CPE=1.0	5.5	87.1	67.9
IW/CPE=1.5	5.6	83.90	58.8
IW/CPE=2.0	5.6	77.7	70.1
S.Em.±	0.048	2.90	7.04
C.D. at 5%	0.109	7.90	26.09
C.V. (%)	3.05	11.81	8.20
Mulch (t/ha)	—	—	—
0	5.37	97.00	58.14
8	5.45	89.33	62.49
12	5.54	83.83	68.00
16	5.63	78.83	71.60
20	5.65	76.83	78.40
S.Em ±	0.04	2.93	3.19
C.D. at 5%	0.08	5.98	6.50
C.D. at 1%	0.112	8.04	8.744
C.V. (%)	—	11.93	16.31

Table 6(c) : Available potassium content (ppm) of soil as influenced by different doses of straw mulches after harvesting of pointed gourd, (Residual effect), 1992.

Doses of straw mulch applied (tonnes/ha)	Available potassium (kg/ha)
00	125
08	180
12	215
16	221
20	277

Table 6(d): Available nitrogen, phosphorus and potassium as influenced by different doses of irrigation and straw mulch in soil, 1993.

Treatments Irrigation	Available nitrogen (kg/ha)	Available pottassium (kg/ha)	Available phosphorus (kg/ha)
IW/CPE=0.5	214	179	16.10
IW/CPE=1.0	236	171	11.10
IW/CPE=1.5	221	177	17.00
IW/CPE=2.0	228	158	15.10
S.Em ±	12.38	9.25	2.072
C.D. at 5%	NS	NS	NS
C.D. at 1%	NS	NS	NS
C.V. %	15.10	14.76	38.36
Mulch (kg/ha)	—	—	—
0	225	103	12.11
8000	245	171	14.77
12000	212	173	15.29
16000	208	183	14.82
20000	232	227	17.00
S.Em ±	16.50	18.77	2.203
C.D. at 5%	NS	38.25	NS
C.D. at 1%	NS	51.44	NS
C.V. (%)	16.50	26.80	36.46

Leaf Area Index And Straw Mulch

The leaf area of the crop were measured with LI-3100 area meter (USA) on different times of the growing season. The leaf area were significantly increased due to mulching on all the years (Fig 16). The basic reason were the difference in the number of leaves as a result of better environment created by application of mulch, Table 7(a), 7(b) and 7(c). The view can be compared from photographs 3a, 3b, 3c, 3d and 3e.

Table 7(a) : Leaf area index as influenced by different doses of straw mulch, 1992

Straw mulch (kg/ha)	Leaf area index 12.8.92	Leaf area index 16.10.92
0	0.428	0.175
8000	0.456	0.313
12000	0.460	0.333
16000	0.484	0.471
20000	0.464	0.440

Table 7(b): Effect of irrigation and mulch on the LAI of pointed gourd, 1993.

Treatments	Leaf area index				
Irrigation	April	June	August	Sept.	Nov.
IW/CPE=0.5	0.4	1.0	0.5	0.7	0.5
IW/CPE=1.0	0.6	1.1	0.4	0.8	0.5
IW/CPE=1.5	0.6	1.0	0.5	0.8	0.5
IW/CPE=2.0	0.5	1.1	0.5	0.8	0.4
S.Em ±	0.109	0.052	0.063	0.052	0.103
C.D. at 5%	NS	NS	NS	NS	NS
C.D. at 1%	NS	NS	NS	NS	NS
C.V. %	56.53	15.06	38.49	17.33	58.55
Mulch (kg/ha)	—	—	—	—	—
000	0.30	0.62	0.24	0.22	0.21
8000	0.44	1.03	0.46	0.56	0.39
12000	0.45	1.10	0.54	0.88	0.44
16000	0.76	1.17	0.50	0.98	0.62
20000	0.73	1.28	0.68	1.33	0.77
S.Em ±	0.057	0.100	0.07	0.100	0.071
C.D. at 5%	0.116	0.230	0.162	0.238	0.145
C.D. at 1%	0.158	0.274	0.194	0.274	0.194
C.V. %	29.03	22.85	33.71	29.92	35.24

Table 7(c) : Leaf area indices of pointed gourd as influenced by different levels of irrigation and mulch, 1994.

Treatments	Leaf area index			
	April	May	June	Sept.
Irrigation	—	—	—	—
IW/CPE=0.5	0.4	0.5	0.8	0.7
IW/CPE=1.0	0.5	0.5	0.7	0.5
IW/CPE=1.5	0.4	0.5	0.7	0.7
IW/CPE=2.0	0.4	0.4	0.6	0.5
S.Em ±	0.052	—	0.08	0.052
C.D. at 5%	NS	NS	NS	NS
C.V. (%)	49.4	45.1	45.44	33.16
Mulch (t/ha)	—	—	—	—
0	0.17	0.16	0.18	0.18
8	0.31	0.35	0.51	0.40
12	0.39	0.44	0.70	0.64
16	0.59	0.64	0.98	0.85
20	0.64	0.72	1.13	1.04
S.Em ±	0.05	—	0.006	0.057
C.D. at 5%	0.10	0.08	0.016	0.116
C.D. at 1%	0.13	0.08	0.016	0.156
C.V. (%)	39.4	28.9	38.18	33.26

The functional relations are shown below for different years.

$$Y_L \text{(Aug. 1992)} = 0.4337 + 0.0022\ X,\ R^2 = 0.71 \quad (48)$$

$$Y_L \text{(April, 1993)} = 0.2681 + 0.0239\ X,\ R^2 = 0.84 \quad (49)$$

$$Y_L \text{(April, 1994)} = 0.15 + 0.0229\ X,\ R^2 = 0.94 \quad (50)$$

where Y_L is the leaf area index and X is the doses of straw mulch in tonnes/ha.

CONCLUSIONS

- Pointed gourd responded well to a irrigation schedule of IW/CPE = 1.55 (optimum) in combination with rice straw mulch @ 14 to 16 (optimum) tonnes/ha. Thirty to 53 cm irrigation water can be saved if mulch is applied @ 15 to 16 tonnes/ha in combination with irrigation at IW/CPE = 1.5 to 1.8 over irrigating the crop at IW/CPE = 2.0 to 2.4 which gives satisfactory high yield.

- Rice straw mulch application increased the fruit production by 77 to 323 percent from 1st year to 4th year of cultivation over no mulch cultivation.

- Seventy five to 135 cm irrigation water is necessary for a good crop of pointed gourd.

- The fruit number per hectare, average length of fruits, average weight of fruit and average fruit thickness were improved by 76 to 300 percent, 7 to 16 percent, 4 to 12 percent and 3 to percent, respectively due to application of straw mulch @ 14 to 16 tonnes/ha with respect to no mulch cultivation.

- Using rice straw mulch @ 20 tonnes/ha as high as 39 percent more soil moisture can be conserved before next irrigation schedule with respect to no mulch cultivation.

- Mulch application maintained 7 to 17 per cent more moisture under different irrigation schedule at 24 hours after application of irrigation over no mulch cultivation.

- In the morning hours, the surface soil and 30 cm deep soil layer remained cooler by 4^0C an 3^0C due to mulcing over no mulcing. At 2.00 P.M. the temperatures were reduced by 10 to 12^0C and 5 to 6^0C respectively on the surface soil and 30 cm deep layer.

- Weeds were significantly controlled by mulching.

- Soil pH and organic matter content of soil were raised due to mulching.

- Redox potential and electrical conductivity were decreased and increased, respectively due to mulch appplication.

- Straw mulch application reduced the available nitrogen content of soil.

- The available phosphorus and potassium were improved due to application of straw mulch in soil. The availability of potassium were increased by two folds due to mulch application.

- Pointed gourd can be cultivated successively upto two consecutive ratoons.

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Pointed gourd crop on mulched bed

Bed and furrow
planting method (no mulch)

Bed and furrow planting method (mulched)

Scanty pointed gourd crop growth (no mulch)

Pointed gourd crop growth @ 8 tonnes mulch/ha.

Pointed gourd crop growth by mulching @ 12 tonnes/ha.

Pointed gourd crop growth by mulching @16 tonnes/ha.

Pointed gourd crop growth by mulching @ 20 tonnes/ha.

Transfer of technology at WTCER farm

Fig.1 Pointed gourd yield Vs. IW/CPE

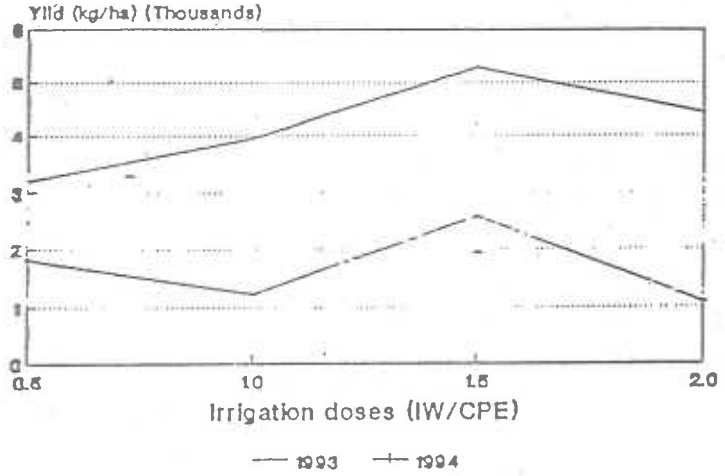

Fig.2 Fruit number Vs. IW/CPE

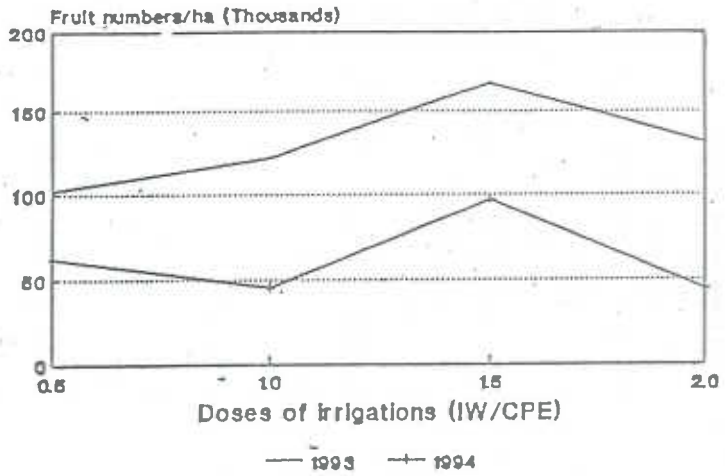

Fig 3. Fruit yield Vs. mulch (kg/ha)

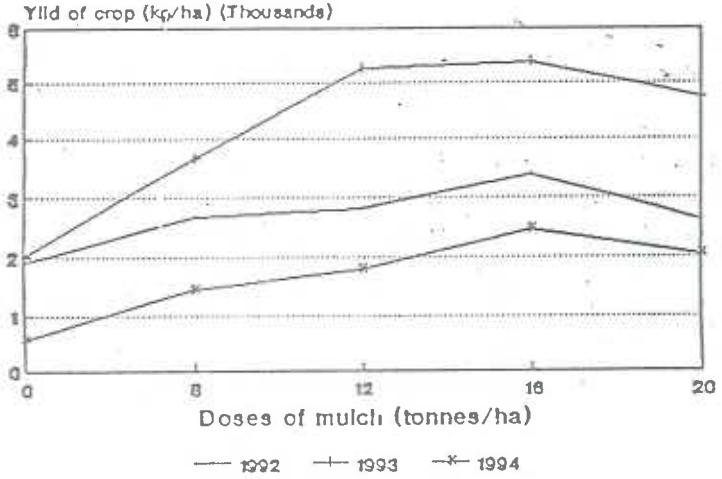

Fig 4. Fruit number Vs. mulch

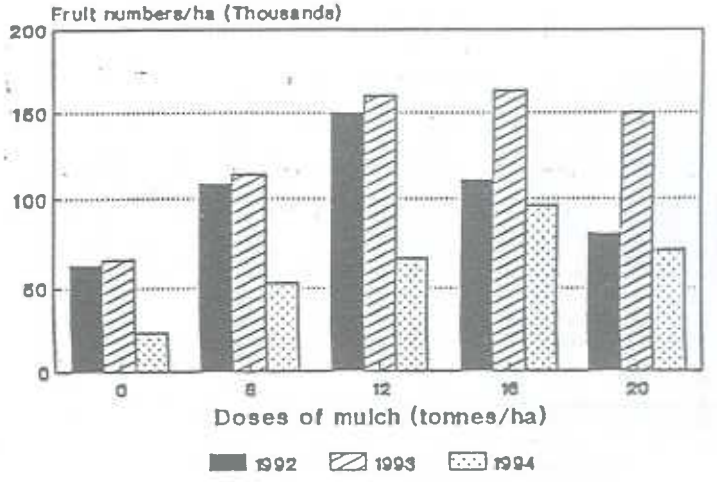

Fig 5. Fruits average weight Vs. mulch

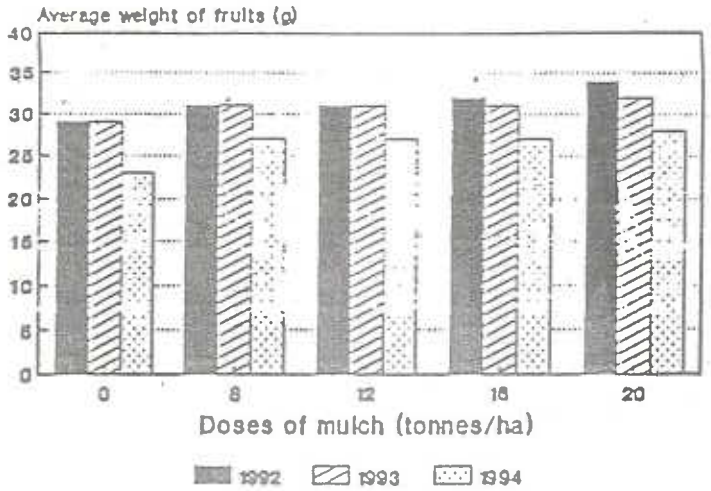

Fig 6. Fruit length Vs. mulch

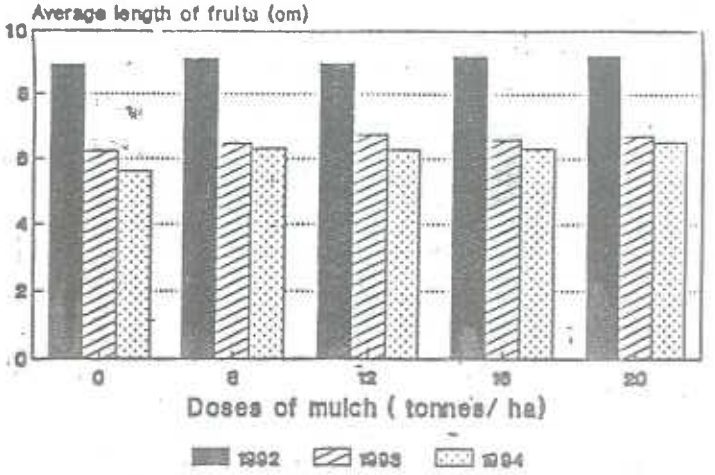

Fig 7. Fruit yield on successive years

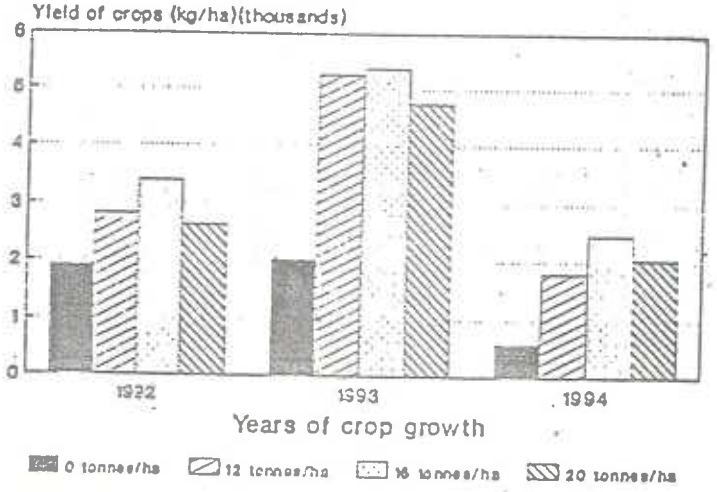

Fig 8. Water stored in 45 cm Vs. mulch Before irrigation

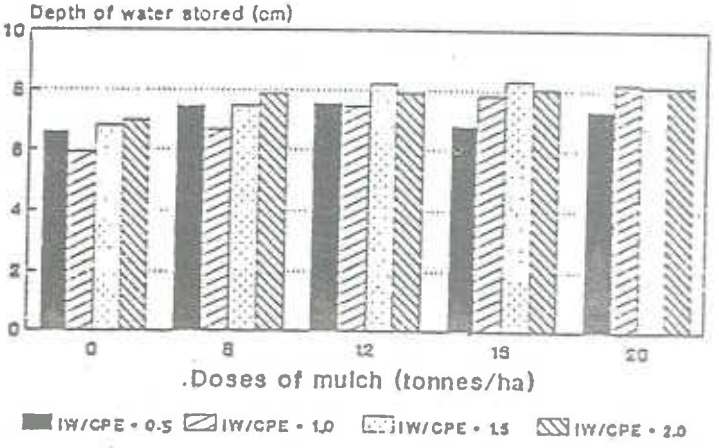

Fig 9. Water stored in 45 cm Vs. mulch
(After irrigation)

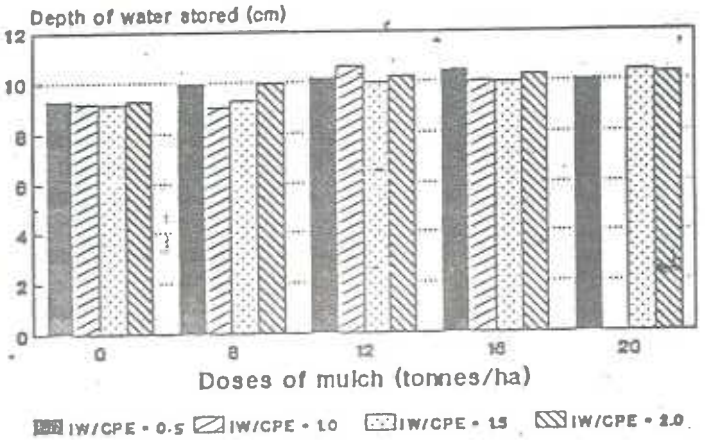

Fig 10. Soil temperature Vs. mulch
(May, 2.00 p.m., surface soil)

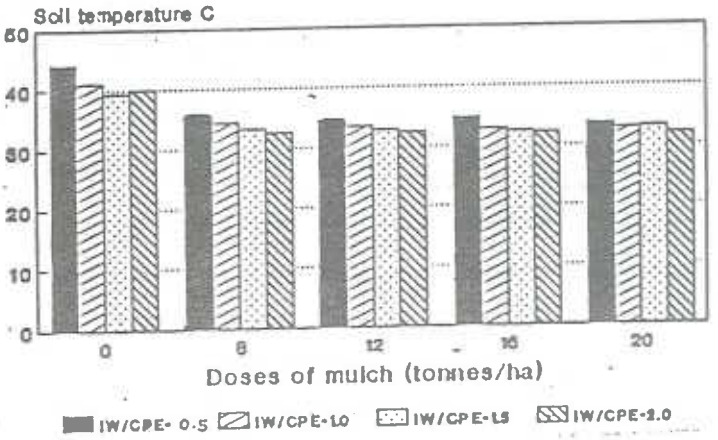

Fig 11. Soil temperature Vs.mulch
(May, 2.00 p.m. 30 cm deep)

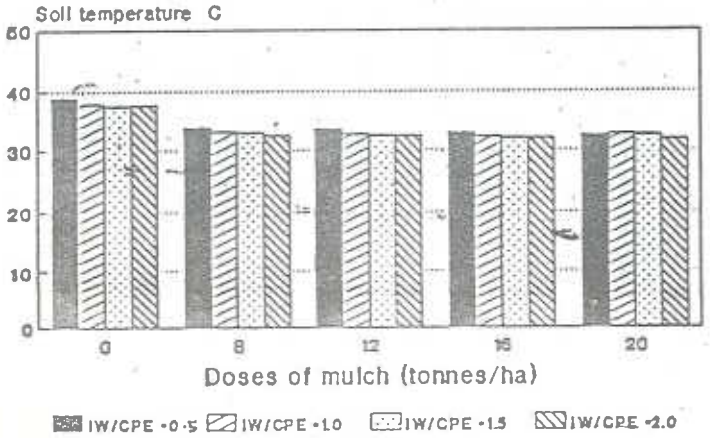

Fig 12. Weed dry matter Vs. mulch
(1993)

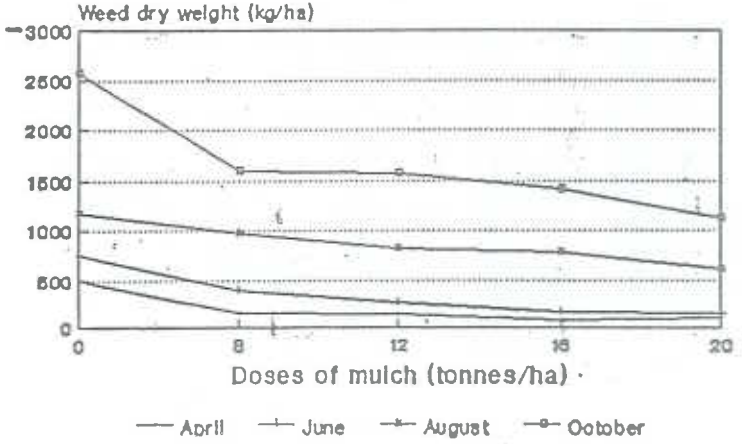

Fig 13. Organic matter content of soil % (1993)

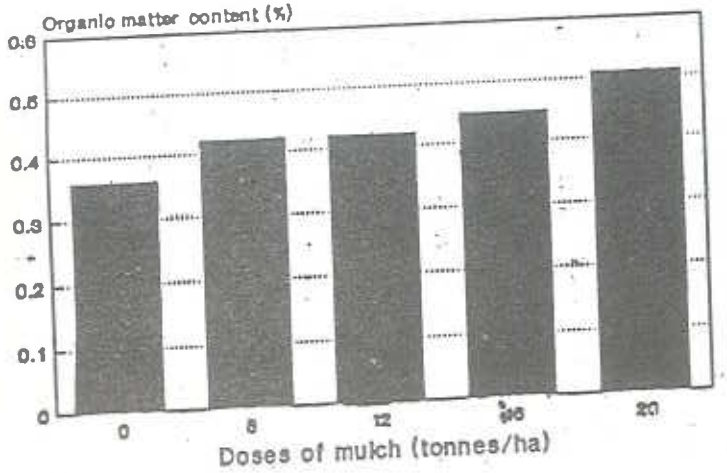

Fig 14. pH of soil

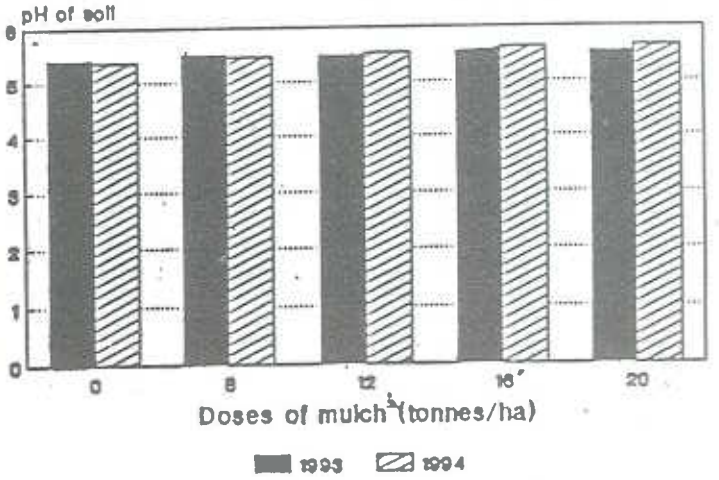

Fig 15. Available potassium and nitrogen

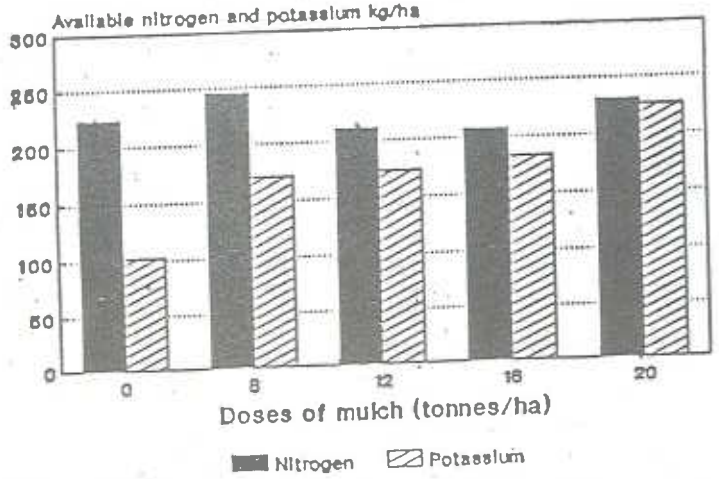

Fig 16.Leaf area Index Vs. mulch (1994)