Indian Journal of Agricultural Sciences **82** (2): 127–33, February 2012

Influence of mulching and irrigation level on water-use efficiency, plant growth and quality of strawberry (*Fragaria ananassa*)

P SURESH KUMAR[1], V K CHOUDHARY[2] and R BHAGAWATI[3]

ICAR Research Complex for NEH region, AP centre, Basar, Arunachal Pradesh 791 101

Received: 30 November 2010; Revised accepted: 15 September 2011

ABSTRACT

Strawberry (*Fragaria* × *ananassa* Duch) cv. Chandler was grown in the field to investigate the effectiveness of different mulches and irrigation level on plant growth, fruit growth, yield and other quality parameters. I_1 favoured plant growth, enhanced flowering (67.5 days), resulted in production of significantly larger fruit and higher yield (175.15 g/plant), higher TSS, and ascorbic acid content with lesser incidence of albinism (17.9%) and botrytis rot than other irrigation levels. Plants mulched with BPM have significantly better growth, flowered and fruited early, produced larger fruit and higher yield, with slightly higher incidence of albinism (19.8%), but with lower incidence of botrytis rot (14.9 %) than those mulched with other materials. Irrigation level × mulching interaction has significantly influenced growth parameters like, crown height, plant spread and leaf area with $I_1 \times M_1$ interaction. Strawberry produced larger fruit (13.1 g) and higher yield (185.8 g/plant), higher TSS, and higher ascorbic acid content with a slightly higher incidence of albinism, but comparatively lower incidence of botrytis rot under irrigation regime of I_1 mulched with black polyethylene.

Key words: Fruit yield, Irrigation, Mulching, Plant growth, Quality, Strawberry

Strawberry (*Fragaria* × *ananassa* Duch.), an octoploid (2n = 56) is a dicotyledonous, perennial low-growing herb grown in most arable regions of the world and is enjoyed by millions of people in all kinds of climates. Strawberries are good sources of natural antioxidants including carotenoids, vitamins, phenols, flavonoids, dietary glutathionine and endogenous metabolites and exhibit a high level of antioxidant capacity against free radical species (Wang and Jiao 2000; Singh *et al*. 2008). In India, during last decade, it has become favourite fruit among growers because of its remunerative prices and higher profitability. Further, availability of day-neutral and high-yielding varieties have resulted in phenomenal increase in its area and production (Sharma *et al*. 2004, Paramanick *et al.* 2005).

Strawberry growth is often suppressed and yields reduced if supplemental water is inadequate or too infrequent during low rainfall months (Singh *et al.* 2007). Irrigation management is critical, because strawberry is sensitive either to water excess or deficit. Improved soil moisture status and increased soil temperatures can also affect soil fertility by influencing the biological activity in soils and, thus, mineralization rates (Asrey and Singh 2004, Sharma 2009). Thus, a mulching experiment under field conditions can provide a measure of temporal fluctuations in soil biochemical properties under several different temperature regimes. The use of mulch has become an important cultural practice in the commercial production of vegetables in many regions of the world to maximize water use and prevent diseases in particular for strawberry (Gupta and Acharya 1993, Shalaby and Mohamed 2005). Mulching also improves plant growth, berry weight, fruit yield and quality in strawberry (Sharma and Sharma 2003, Singh and Asrey 2005). However, the effects of use of different irrigation level in combination with different mulch types on physiology, nutrition, and yield has not been studied intensively. Considering these facts, there is a pressing need to lay out the field experiment with strawberry cultivar, Chandler, to evaluate strawberry health and yield.

MATERIALS AND METHODS

The field experiment was carried out in clay-loam soil at the experimental farm of ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, lying at 26° 28´ to 29° 28´ N latitude and 91° 35´ to 97° 27´ E longitude, 631m above MSL, located at West Siang District of Arunachal

[1]Scientist (Horticulture), (e mail: psureshars@gmail.com), CTCRI, Trivandrum, Kerala;

[2]Scientist (Agronomy), (e mail: ind_vc@rediffmail.com), [3]Joint Director (e mail: r_bhagawati@rediffmail.com), ICAR RC NEHR, AP Centre

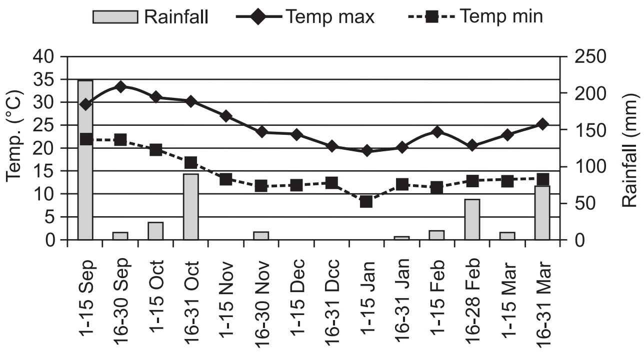

Fig 1 Weather conditions prevailed during experiemntal period (average of two consecutive study period)

Pradesh during 2009 and 2010. The area falls under the humid sub-tropical climate. The daily temperature during the study period varies widely between maximum 31.2°C, minimum 8°C and, received average rainfall of 507 mm (Fig 1). The physical and chemical properties of the soils are clay loam in texture, acidic in reaction (*p*H 5.3), high in organic carbon (1.50 g/ kg), available N (205.6 kg/ ha), available phosphorus (8.3 kg/ ha) and available K (260 kg/ ha). Moisture retention at 0.03 and 1.5MPa, bulk density and saturated hydraulic conductivity were 29.6% and 17.2%, 1.45 Mg/m^3 and 532.1 mm/hr respectively, in 0–20 cm soil depth.

Soil was thoroughly ploughed and raised beds of 20 cm height and one meter width were prepared at a distance of 50 cm. The experiment was laid out in split-plot design, with three irrigation level as main effect, and four mulching materials as sub-main effect in random blocks with three replicates, in 36 plots. Healthy and disease-free runners of Chandler strawberry, with one well-developed crown of diameter 8–10 mm were planted in the mid of September at a spacing of 25 cm × 25 cm. During the early stage of plant establishment, irrigations were performed manually, twice a day. Each treatment combination consisted of 144 plants in a plot size of 900 cm × 100 cm. Three water potential levels in the soil were used in order to determine irrigation time, corresponding to I_1:1.0 IW/CPE ratio, I_2:0.8 IW/CPE ratio and I_3:0.6 IW/CPE ratios. Irrigation water (flood irrigation) was measured by parshall flume and total of 6, 4 and 3 numbers of irrigation of 5cm each at IW/CPE ratio of 1.0, 0.8 and 0.6, respectively were provided during both the seasons. All irrigation treatments were imposed three weeks after planting. The duration interval of irrigation was calculated from the product of pan evaporation. Mulching treatment consisted of black polyethylene film (M_1:BPM; 50 µm); transparent polyethylene film (M_2:TPM; 50 µm), paddy straw mulch (M_3:PSM; 10 cm thickness/ 4tonnes/ha) and pine mulch (M_4:PM; 10 cm thickness/ 4tonnes/ha). Mulches were applied 25 days after planting of runners. The plots were lined with polythene to protect from seepage and buffer channels were made to reduce the entry of water to experimental plots.

Observations on crown height (cm), plant spread (cm^2), leaf area (recorded by leaf area meter in cm^2); days taken to flowering and fruiting were recorded. The fruits were harvested from 20 randomly selected plants/replicate from each treatment combination at the 3/4 ripe stage, twice-weekly, and were classified as marketable and non-marketable. Fruits containing rots (*Botrytis* rot), physical imperfections (albinism), or attacked by insects or birds were considered non-marketable. After classification, the fruits were counted and weighed expressed as fruit weight and fruit yield/plant. Root parameters, viz number of roots, maximum root length, root volume, root dry weight and root density were recorded. For incidence of albinism, healthy (normal) and albino fruit were counted and represented as percentage (%). For botrytis fruit rot infection, infected fruit were counted as and when symptoms of the infection were noticed and were represented as percentage (%). A sample of 10 fruit halves was wrapped in cheesecloth and squeezed with a hand press, and the clear juice was analyzed for total soluble solids (TSS), titratable acidity (TA), ascorbic acid content (mg/100 g pulp), anthocyanin and reducing sugar (AOAC, 1989). Soil temperature was measured with the help of soil thermometer during clear sunny days at 1.00 pm at the fruiting stage of strawberry (February) by installing at 20 cm depth in all the plots. Water use efficiency was measured by the ratio of yield harvested to the volume of water used. Collected data on various parameters were pooled and analyzed using AGRES statistical computer program and significance was identified at 5% level while non- significant results were denoted as NS. However, data on albinism incidence and botrytis fruit rot infection (%) were transformed as per Arc sin's values before analysis.

RESULTS AND DISCUSSION

Soil temperature

The soil temperature was measured periodically during the experiment and irrespective of months, the irrigation with the IW/CPE of 0.6 recorded the maximum and minimum soil temperature throughout the experiment, followed by 0.8

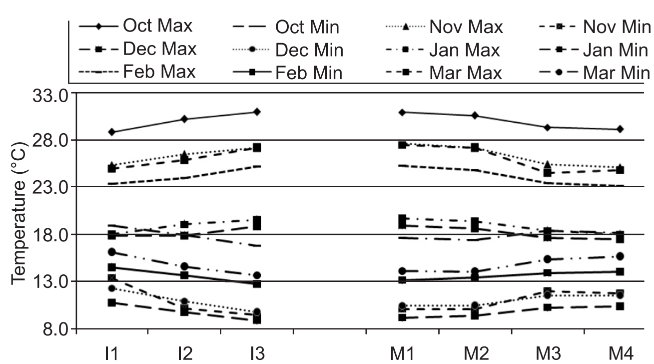

Fig 2 Effect of irrigation levels and soil mulches on soil temperature in strawberry (average of two consecutive study period)

(Fig 2). This might be due to higher specific heat of water than soil and air. The fluctuation in soil temperature was lower in case of 1.0 IW/CPE due to the higher specific heat of water (Sharma 2009). Among the various mulches BPM recorded the higher soil temperature during mid day followed by TPM. The higher soil temperature on BPM is due to absorption of solar radiation and transfer the heat to soil surface which leads to increase in soil temperature (Singh *et al.* 2007).

Plant growth and development

Plant growth parameters, like crown height, plant spread and leaf area of Chandler strawberry were significantly influenced by irrigation level, mulching and their interaction (Table 1). Irrespective of mulching, crown height, plant spread and leaf area of the plants were recorded higher in I_1 (1.0 IW/CPE ratio) than other irrigation level. Result showed that irrigation level in strawberry produces very significant changes in growth and development of plant including root growth and dry biomass. It is well known that as soil water availability is limited, plant growth is usually decreased. More recent studies, have shown that stem and leaf growth may be inhibited at low water potential despite complete maintenance of turgor in the growing regions as a result of osmotic adjustment (Pires *et al.* 2007, Sharma 2009).

Similarly, crown height (11.03 cm), plant spread (23.3 cm^2) and leaf area (86.6 cm^2) were significantly higher in plants mulched with black polyethylene than those mulched with other materials. It may be attributed to better soil hydrothermal regimes, better moisture conservation and suppression of weeds than other mulches (Gupta and Acharya 1993). Many researchers have also reported better growth of strawberry plants under mulch (Sharma and Sharma 2003, Singh and Asrey 2005, Singh *et al.* 2007). Further, the interactive effect of irrigation level × mulching, showed that crown height, plant spread and leaf area were highest in $I_1 \times M_1$ (BPM) and lowest in $I_3 \times M_4$ (PM). It may be attributed to synergistic and interactive influence of treatments on creation of comparatively favourable environment and better moisture conservation, suppression in weed growth. Similar results were reported by Singh *et al*. (2007) on strawberry.

Days to flowering and fruiting

Interesting observations were recorded on effects of irrigation level, mulching and their interaction on flowering and fruiting of strawberry (Table 1). Plants took more days

Table 1 Growth and yield attributes as influenced by irrigation and mulches in strawberry (pooled data of both the seasons)

Treatment	Crown height (cm)	Plant spread (cm^2)	Leaf area (cm^2)	Days taken to flowering	Days taken to fruiting	Fruit weight (g)	Fruit yield/ plant (g)
I_1M_1	11.4	24.4	88.5	77.3	55.3	13.1	185.8
I_1M_2	9.9	21.5	82.3	75.6	52.1	11.4	179.1
I_1M_3	10.8	21.6	83.1	72.7	49.9	10.9	170.3
I_1M_4	9.5	19.3	80.2	70.4	46.2	9.9	165.4
I_2M_1	11.0	23.1	86.7	76.2	52.4	12.8	180.2
I_2M_2	9.4	20.7	81.4	73.3	49.3	11.1	173.5
I_2M_3	10.2	20.5	79.8	69.4	47.4	10.7	163.1
I_2M_4	9.1	18.6	75.6	68.2	46.8	9.3	162.4
I_3M_1	10.7	22.3	84.8	70.5	49.2	12.2	170.8
I_3M_2	8.8	19.4	74.1	68.8	47.6	10.7	163.6
I_3M_3	9.4	19.0	70.9	66.5	45.2	9.6	141.3
I_3M_4	8.2	17.4	66.8	64.2	44.7	8.0	133.5
				IW/CPE ratio			
I_1	10.4	21.7	83.5	73.9	50.8	11.3	175.2
I_2	10.0	20.7	80.9	71.7	48.9	11.0	169.7
I_3	9.3	19.5	74.1	67.5	46.7	10.1	152.3
				Mulches			
M_1	11.1	23.3	86.7	74.7	52.3	12.7	178.9
M_2	9.4	20.5	79.3	72.5	49.7	11.1	172.1
M_3	10.1	20.4	77.9	69.5	47.5	10.4	158.2
M_4	8.9	18.4	74.2	67.6	45.9	9.1	153.8
				CD (P=*0.05*)			
I	0.30	0.43	4.3	2.4	1.5	0.69	9.5
M	0.27	0.61	3.2	2.8	1.7	0.49	9.7
I × M	N.S.	0.81	5.5	3.5	2.3	0.86	16.8

to flowering in I_1 level, and comparatively lesser days in I_3 irrigation level. Similarly, I_3 took lesser days for fruiting than those plants imposed with other irrigation level. This may be due to the fact that moisture stress compelled the plants to complete basic vegetative earlier and induce to plant to synthesis the flowering hormone which helped in formation of flower buds. Similarly, BPM and PSM took little larger time to complete the basic vegetative stage and to synthesize organic molecule for flowering than the TPM and PM. Similar result was observed by Choudhary *et al.* (2006) in baby corn. Further, the interactive effect of Irrigation level × mulching was much more significant as plants took lesser days to flowering at I_3M_4, whereas those planted with I_1M_1 combination took as high as 77.3 days. Further, different mulching materials affected the flowering and fruiting in Chandler strawberry mainly because of differed soil hydrothermal regimes. Yellow or white mulches reflect radiant energy and reduce soil temperatures (Kirnak *et al.* 2001), whereas dark polyethylene mulches absorb incident radiation and transmit it to the soil via conduction. The interactive effect of irrigation level and mulching has positive and significant influence on advancement of flowering and fruiting. However it was noticed that early fruits were comparatively smaller in sizes which in turn reduce the overall yield of the plant in those experimental plots.

Fruit weight and yield

Larger fruit (11.32 g) were harvested from I_1 level than those imposed with either in I_2 (10.97 g) or I_3 (10.13 g). I_1 level also produced significantly higher fruit yield (175.15 g/ plant) compared to other level. Likewise, mulching also influenced the fruit weight and yield/plant significantly. Fruits were comparatively larger in plants mulched with BPM than TPM, PSM and PM. Correspondingly, fruit yield/plant was significantly higher in plants mulched with BPM (178.93 g/ plant). Plants under BPM produced larger fruit and have higher yield/plant, mainly because of better plant growth owing to favourable hydrothermal regime of soil and complete weed free environment (Sharma and Sharma 2003, Singh and Asrey 2005). Although, plants under TPM also have better plant growth, but berry weight and fruit yield/plant were lesser than plants mulched with PSM. Present observations (data not shown) in this regard revealed that weeds were not completely suppressed by TPM might have resulted into produce smaller fruit with low yield/plant. Gupta and Acharya (1993) have also reported that emergence of weeds is quite common in clear plastic films, which hinders the plant growth and fruit yield/plant adversely. Irrigation level × mulching interaction for fruit weight and yield was highly significant, as fruit harvested from I_1M_1 treatment recorded largest fruit weight and maximum yield/plant. This study confirms that mulching, almost totally mitigated the adverse effects of low irrigation level on field-grown strawberry, restoring most of the key growth and yield parameters to higher levels. It may be attributed to synergistic influence of water and BPM for better growth and development of plants, better soil-hydrothermal regimes and weed free environment (Gupta and Acharya 1993, Singh *et al.* 2006).

Root parameters

The root parameters, viz number of roots, maximum root length, root volume, root dry weight and root density was recorded significantly with irrigation ratios and mulches (Table 2). Root numbers was recorded higher when crop was imposed with 1.0 IW/CPE ratio. However, parameters like maximum root length, root volume and root dry weight was higher on lower ratios. Most of the photosynthates translocated and used to produce fibrous roots and rest was utilized for normal growth and development with I_1 level. Similar findings were reported by Choudhary *et al* (2006) in baby corn. The unavailability of water in the surface, induced the plants to extend its roots to grow deeper which ultimately translocated the photosynthates for root growth and development. It was also noticed that in higher irrigation level, roots were more fibrous and branched. It is evident that root growth was less

Table 2 Root parameters as influenced by irrigation and mulches in strawberry (pooled data of both the seasons)

Treatment	Root no.	Root length (cm)	Root density (g/cm^3)	Root weight (g)	Root volume (cm^3)
I_1M_1	21.1	25.0	0.22	3.03	14.13
I_1M_2	20.3	25.4	0.21	3.10	14.67
I_1M_3	18.8	27.2	0.23	3.50	15.27
I_1M_4	18.2	27.9	0.23	3.67	15.76
I_2M_1	19.3	26.2	0.23	3.23	14.36
I_2M_2	17.0	25.9	0.25	4.23	16.93
I_2M_3	15.4	30.4	0.30	5.20	17.45
I_2M_4	14.2	30.6	0.30	5.30	18.00
I_3M_1	17.5	28.7	0.25	4.03	16.22
I_3M_2	16.2	29.9	0.27	4.70	17.33
I_3M_3	13.8	31.2	0.31	5.63	18.29
I_3M_4	13.2	32.1	0.31	5.83	18.87
		IW/CPE ratio			
I_1	19.6	26.4	0.22	3.33	14.96
I_2	16.5	28.3	0.27	4.49	16.69
I_3	15.2	30.5	0.29	5.05	17.65
		Mulches			
M_1	19.3	26.6	0.23	3.43	14.90
M_2	17.8	27.1	0.24	4.01	16.31
M_3	16.0	29.6	0.28	4.78	16.98
M_4	15.2	30.2	0.28	4.93	17.54
		CD (P=*0.05)*			
I	0.36	1.43	0.028	0.30	0.36
M	0.41	1.66	0.022	0.35	0.41
I × M	0.71	N.S.	N.S.	0.61	0.72

Table 3 Chemical parameters and disease incidence as influenced by irrigation and mulches in strawberry (pooled data of both the seasons)

Treatment	TSS (%)	Acidity (%)	Reducing sugar (%)	Vit C (mg/100 g)	Anthocyanin (mg/100 g)	Albinism (%)	Botrytis rot (%)
I_1M_1	8.31	0.84	2.84	55.3	25.7	10.4(18.8)	6.4(14.6)
I_1M_2	8.17	1.11	2.76	49.4	24.5	9.2 (17.6)	7.5(15.9)
I_1M_3	7.81	1.03	2.81	51.1	25.0	9.3 (17.7)	6.9(15.2)
I_1M_4	7.63	1.16	2.73	46.8	24.2	9.0(17.5)	8.0(16.4)
I_2M_1	8.22	0.95	2.80	53.1	25.6	11.9(20.2)	6.5(14.8)
I_2M_2	7.81	1.14	2.71	48.5	24.1	10.4(18.8)	7.6(16.0)
I_2M_3	7.74	1.06	2.75	50.7	24.5	10.8(19.2)	6.8(15.1)
I_2M_4	7.51	1.20	2.64	45.3	23.2	10.0(18.4)	8.2(16.6)
I_3M_1	8.03	0.99	2.78	49.1	24.7	12.3(20.5)	6.9(15.2)
I_3M_2	7.24	1.19	2.73	44.7	23.6	10.9(19.3)	7.9(16.3)
I_3M_3	7.63	1.12	2.74	45.6	24.1	11.1(19.4)	7.5(15.9)
I_3M_4	7.47	1.22	2.65	41.3	23.8	10.5(18.9)	8.8(17.3)
IW/CPE ratio							
I_1	7.981	1.035	2.785	50.652	24.851	17.91	15.5
I_2	7.819	1.088	2.727	49.401	24.350	19.1	15.6
I_3	7.593	1.130	2.725	45.174	24.052	19.5	16.2
Mulches							
M_1	8.186	0.927	2.808	52.501	25.334	19.83	14.9
M_2	7.742	1.147	2.733	47.534	24.069	18.57	16.1
M_3	7.727	1.070	2.768	49.133	24.533	18.76	15.4
M_4	7.537	1.193	2.673	44.467	23.733	18.26	16.8
CD (P = 0.05)							
I	0.226	0.033	0.102	1.826	1.228	0.348	0.316
M	0.374	0.051	0.123	2.172	0.975	0.428	0.345
I × M	NS	0.090	NS	3.765	1.696	0.734	0.587

inhibited than shoot growth under low irrigation level. This observation is in agreement with studies conducted by Sharp (1996) who reported that some roots continue to elongate at low soil water potentials that completely inhibit shoot growth. Spollen *et al.* (1993) also found that the primary roots in several crop species can maintain significant elongation rates at low water potential, whereas shoot elongation is much more sensitive. The beneficial effect of mulch covers in reducing water stress is probably due to minimizing water loss from the soil surface as well as regulating soil temperature in the root zone (Kirnak *et al.* 2001). In TPM, growth of weeds was higher which have higher transpiration coefficient, this causes stress in plant. So, most of the photosynthates were translocated towards below ground portion for growth and development. This leads the plant to have maximum root length, root numbers, root volume and root dry weight.

Fruit quality parameters

TSS, ascorbic acid, reducing sugar and anthocyanin content were comparatively higher in fruit harvested from I_1 irrigation level than those harvested from other irrigation levels (Table 3). Similarly, fruit harvested from plants, which were mulched with BPM recorded better TSS, lower acidity, higher ascorbic acid content (52.50 mg/100 g pulp), reducing sugar and anthocyanin than fruit obtained from plants mulched with other materials. The data presented here clearly showed that using BPM, TPM and PSM mulches can significantly mitigate the adverse effect of low irrigation on fruit yield and quality. Present study showed that BPM significantly affect strawberry yield and growth parameters at $P = 0.05$. Singh *et al.* (2007) have reported that increased temperature has negative effect on fruit quality parameters in strawberry and mulching influences quality of strawberry invariably. It may be attributed to favourable climatic conditions and creation of weed free environment by black mulch polyethylene in fields, which led to higher TSS and ascorbic acid content and lower acidity in fruit (Gupta and Acharya 1993, Hassan *et al.* 2000, Sharma *et al.* 2004). The interactive effect of Irrigation × mulching for all quality parameters were also significant. It may be attributed to cumulative and synergistic effect of mulches with irrigation, due to which, plants have better growth, early flowering and fruiting, and accumulation of quality traits (Singh *et al.* 2007). Incidences of albinism and botrytis rot were significantly influenced by irrigation and mulching individually and in combination (Table 3). Irrespective of mulching, 1.0 IW/CPE ratio produced lesser

Table 4 Water management and water-use efficiency in strawberry (pooled data of both the seasons)

Treatment	No. of irrigation	Effective rainfall (mm)	Irrigation water (mm)	Consumptive water use (ha-mm)*	Water applied (litre/plant)	Yield (g/plant)	WUE (g/plant-lit)
				IW/CPE ratio			
I1	6	237.4	300	537.4	33.60	175.2	5.21
I2	4	237.4	200	437.4	27.50	169.8	6.17
I3	3	237.4	150	387.4	24.20	152.3	6.29
				Mulches			
M1				454.1	28.4	178.9	6.30
M2				454.1	28.4	172.1	6.06
M3				454.1	28.4	158.2	5.57
M4				454.1	28.4	153.8	5.42

* Consumptive water-use includes effective rainfall and irrigation, contribution from the soil profile was considered as zero.

albino and botrytis rot infected fruit than other irrigation level. Plants mulched with BPM, in spite of producing bit higher albino fruit, were lesser infected by botrytis rot compared to other mulches. This may be attributed to higher thermal heat, which is produced at the surface of film, as black polyethylene has the capacity to absorb higher solar radiation than other mulch materials. Further, black polyethylene film is also considered to activate microbial and other chemical reactions in the soil (Gupta and Acharya 1993), which might have promoted the incidence of albinism. Similar findings of higher incidence of albinism with the use of black polyethylene have also been reported by Sharma and Sharma (2003) and Sharma *et al*. (2004). In contrast, botrytis fruit rot infection was lesser in plants mulched with black polyethylene and higher in plants mulched with paddy straw, primarily because straw is considered as a better medium for the spread of *Botrytis cinerea* than black polyethylene mulch (Sharma *et al.* 2004).

Water management

Water-use efficiency was recorded higher on 0.6 IW/CPE, followed by 0.8 (Table 4). This might be due to the fact that plants grown under the lower IW/CPE responded more to the applied water and produced sufficient berries/plant. The amount of water applied was fully utilized and loss of water through evaporation and percolation was limited due to less exposed surface area and slow rate of supply (Pires *et al.* 2007). However, at higher ratio the most of the water was evaporated from the surface. Therefore, the WUE was comparatively lesser than lower ratios. Among various mulches, BPM recorded the highest WUE, followed by PSM. This may be due the higher yield recorded from the BPM by better availability of applied water, reduced loss of water by evaporation, percolation and lower weed population throughout the crop growth period (Singh *et al*. 2007). However, the lowest WUE was recorded on PM, followed by TPM due to lower yield.

The study concluded that Chandler strawberry could be planted with supplemented irrigation at 1.0 (IW/CPE ratio) with black polyethylene mulch which favoured better growth with higher yield. Irrigation with 0.6 and 0.8 IW/CPE saves 38.8 and 12.1% water over 1.0 IW/CPE and recorded 15.0 and 3.2% lower yield over 1.0 IW/CPE. Among the mulches, BPM recorded 16.3% higher yield over PM, followed by 11.9% by TPM.

REFERENCES

AOAC 1989. *Official Methods of Analysis*, 14th edn. Association of Official Agricultural Chemists, Washington, DC.

Asrey R and Singh R. 2004. Evaluation of strawberry varieties under semi-arid irrigated region of Punjab. *Indian Journal of Horticulture* **61**: 122–4.

Choudhary, V.K., Ramachandrappa, B K. and Nanjappa, H V., 2006, Influence of planting methods and drip irrigation levels on total water requirement, yield, water use efficiency and root characters in Baby corn (*Zea mays* L.). *Mysore Journal of Agricultural Sciences* **40**(2): 189–93.

Gupta R and Acharya C L. 1993. Effect of mulch induced hydrothermal regime on root growth, water-use efficiency, yield and quality of strawberry. *Journal of Indian Society of Soil Science* **41**: 17–25.

Hassan G I, Godara A K, Kumar J and Huchehe A D. 2000. Effect of different mulches on yield and quality of 'Oso Grande' strawberry. *Indian Journal of Agricultural Sciences* **70**: 184–5.

Kirnak H, Kaya C, Higgs D and Gercek S. 2001. A long-term experiment to study the role of mulches in the physiology and macro-nutrition of strawberry grown under water stress. *Australian Journal of Agricultural Research* **52**: 937–43.

Paramanick K K, Kishore D K and Sharma S K. 2005. Commercial strawberry cultivation in the nurseries as well as urban areas in India. *Advances in Horticultural Sciences* **19**: 34–41.

Pires R C M, Folegatti M V, Tanaka M A, Passos F A, Ambrosano G M B and Sakai E. 2007. Water levels and soil mulches in relation to strawberry diseases and yield in a greenhouse. *Scientific Agricuture* **64** (6): 575–81.

Sharma R R and Sharma V P. 2003. Mulch influences fruit growth, albinism and fruit quality in strawberry (*Fragaria x ananassa* Duch). *Fruits* **58**: 221–27.

Sharma R R, Sharma V P and Pandey S N. 2004. Mulching influences plant growth and albinism disorder in strawberry under subtropical climate. *Acta Horticulturae* **662**: 187–91.

Sharp R E. 1996. Regulation of plant growth responses to low soil water potential. *Hort Science* **31**: 36–8.

Singh R and Asrey R. 2005. Growth, earliness and fruit yield of microirrigated strawberry as affected by time of planting and mulching. *Indian Journal of Horticulture* **62** (2): 148–51.

Singh R, Sharma R R and Goyal R K. 2007. Interactive effects of planting time and mulching on 'Chandler' strawberry (*Fragaria* × *ananassa* Duch.). *Scientia Horticulturae* **111**(4): 344–51.

Singh A, Patel R K, De L C and Periera L S. 2008. Performance of strawberry cultivars under subtropics of Meghalaya. *Indian Journal of Agricultural Sciences* **78** (7): 1–4

Spollen W G, Sharp R E, Saab I N and Berstein N. 1993. Regulation of cell expansion in roots and shoots at low water potentials. *Journal of Experimental Botany* **45**:1743–51.

Wang S Y and Jiao H. 2000. Scavenging capacity of berry crops on superoxide radicals, hydrogen peroxide, hydroxyl radicals, and singlet oxygen. *Journal of Agriculture and Food Chemistry* **48**: 5677–86.