

Effect of mulches on growth, production and quality of
Strawberry (*Fragaria x ananassa* Duch.) cv. Winter Dawn
under different growing environments

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SWAPNIL PANDEY

Thesis

Master of Science in Horticulture
(Fruit Science)



2014

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF HORTICULTURE AND FORESTRY, JHALAWAR

MAHARANAPRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

UDAIPUR-313001 (RAJASTHAN)

**MAHARANAPRATAP UNIVERSITY OF AGRICULTURE
& TECHNOLOGY, UDAIPUR**

**COLLEGE OF HORTICULTURE & FORESTRY, JHALARAPATAN,
JHALAWAR-326 023 (RAJ.)**

CERTIFICATE - I

Date:

This is to certify that **Ms. SWAPNIL PANDEY** had successfully completed the Comprehensive Examination held on 3rd June, 2014 as required under the regulation for **Master of Science in Horticulture (Fruit Science)**.

Head

Department of Fruit Science,
College of Horticulture & Forestry,
Jhalarapatan, Jhalawar-326023
(Rajasthan)

**MAHARANAPRATAP UNIVERSITY OF AGRICULTURE
& TECHNOLOGY, UDAIPUR**

**COLLEGE OF HORTICULTURE & FORESTRY, JHALARAPATAN,
JHALAWAR-326 023 (RAJ.)**

CERTIFICATE - II

Date:

This is to certify that the this thesis entitled “**Effect of mulches on growth, production and quality of Strawberry (*Fragaria x ananassa*Duch) cv. Winter Dawn under different growing environments**” submitted for the degree of **Master of Science in Horticulture** in the subject of **Fruit Science** embodies bonafide research work carried out by Ms. Swapnil Pandey under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on 4th June, 2014.

Forwarded by :

(Jitendra Singh)

Head

Department of Fruit Science

Major Advisor

Dean

College of Horticulture & Forestry,

Jhalawar (Raj.)

**MAHARANAPRATAP UNIVERSITY OF AGRICULTURE &
TECHNOLOGY, UDAIPUR**

**COLLEGE OF HORTICULTURE & FORESTRY,
JHALARAPATAN, JHALAWAR-326 023 (RAJ.)**

CERTIFICATE - III

Date: . . .

This is to certify that this thesis entitled “**Effect of mulches on growth, production and quality of Strawberry (*Fragaria x ananassa*Duch) cv. Winter Dawn under different growing environments**” submitted by Ms. Swapnil Pandey to Maharana Pratap University of Agriculture and Technology, Udaipur in partial fulfilment of the requirements for the degree of **Master of Science in Horticulture** in the subject of **Fruit Science** after recommendation by the external examiner was defended by the candidate before the following members of examination committee. The performance of the candidate in the oral examination was satisfactory; we therefore, recommend that this thesis be approved.

(Dr. Jitendra Singh)

Major Advisor

(Dr. Prerak Bhatnagar)

Advisor

(Dr. Kavita A.)

Advisor

(Dr. S. K. Jain)

DRI Nominee

(Dr. M. C. Jain)

Head

Department of Fruit

Science

(Dr. L. K. Dashora)

Dean

College of Horticulture & Forestry,

Jhalarapatan, Jhalawar (Raj.)

APPROVED

()

Director Resident Instructions,

Maharana Pratap University of Agriculture and Technology, Udaipur

**MAHARANAPRATAP UNIVERSITY OF AGRICULTURE
& TECHNOLOGY, UDAIPUR**

**COLLEGE OF HORTICULTURE AND FORESTRY,
JHALARAPATAN, JHALAWAR-326 023 (RAJ.)**

CERTIFICATE - IV

Date :

This is to certify that Ms. Swapnil Pandey student of Master of Science in Horticulture in the Department of Fruit Science has made all corrections/modifications in the thesis entitled “**Effect of mulches on growth, production and quality of Strawberry (*Fragaria x ananassa*Duch) cv. Winter Dawn under different growing environments**” which were suggested by the External Examiner and the Advisory Committee in the oral examination held on The final copies of the thesis duly bound and corrected were submitted on

(Dr. Jitendra Singh)

Major Advisor

(Dr. M. C. Jain)

Head

Department of Fruit Science

(Dr. L. K. Dashora)

Dean

College of Horticulture & Forestry
Jhalarapatan, Jhalawar- 326 023 (Raj.)

Effect of mulches on growth, production and quality of Strawberry (*Fragaria x ananassa*Duch.) cv. Winter Dawn under different growing environments

SWAPNIL PANDEY*

DR. JITENDRA SINGH**

P.G. Scholar

Major Advisor

ABSTRACT

A field experiment entitled “Effect of mulches on growth, production and quality of Strawberry (*Fragaria x ananassa*Duch.) cv. Winter Dawn under different growing environments” was conducted at the Protected Cultivation Unit, College of Horticulture and Forestry, Jhalawar during 2013-2014. The experiment consisted of sixteen treatments comprising different mulch materials viz. No mulch (M_0), Rice husk (M_1), White polythene (M_2) and Black polythene (M_3) under different growing environments viz. Open field (T_0), Agro shade net (T_1), Naturally ventilated polyhouse (T_2) and Fan pad system greenhouse (T_3). The experiment was laid out in Randomized Block Design with three replications.

As regard to growth parameters, treatment M_1T_2 : Rice husk+Naturally ventilated polyhouse had the maximum crown height (29.33cm), petiole length (20.27cm) and fresh weight(235.00g) and dry weight(57.28g) of plant. However, maximum number of leaves per plant (97.44) and total chlorophyll content (3.26mgg⁻¹) was recorded in the treatment M_2T_0 : White polythene+Open field. Plant E-W spread and N-S spread was observed maximum (51.80cm and 49.88cm, respectively) in the treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse. Treatment M_3T_3 : Black polythene+Fan pad system greenhouse recorded maximum (4.00) runner production per plant.

In production parameters, treatment M_3T_0 : Black polythene+Open field produced maximum fruit length (54.00mm), fruit width (42.59mm), fresh weight (36.74g) and dry weight(2.88g) of fruit and also fruit yield per plant (536.55g). Minimum days to first flower initiation (21.66 days), 50 per cent flowering (82.77 days) and first fruit set (26.44 days) was recorded in the treatment M_3T_3 : Black polythene+Fan pad system greenhouse. Maximum harvest period (139.44 days), number of pickings (26.00), length: diameter ratio (1:30) and number of fruits per plant (39.66) were observed in the treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse. Minimum number of days (89.00 days) required to 50 per cent fruit set was noted in the treatment M_2T_2 : White polythene+Naturally ventilated polyhouse, whereas, minimum number of days (52.30 days) to first harvest was recorded in the treatment M_1T_0 : Rice husk+Open field.

Better quality parameters viz. maximum TSS (7.30°B), Vit.C content (52.54mg100g⁻¹), total (5.15 per cent) and reducing sugar (4.06 per cent, respectively), juice content (96.10 per cent) and also overall sensory score (8.35) were observed in treatment M_3T_0 : Black polythene+Open field. Minimum titratable acidity (1.45 per cent),

maximum TSS/acid ratio (4.97) and maximum anthocyanin content ($45.51 \text{ mg}100\text{g}^{-1}$) was recorded in the treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse.

In most of the root growth parameters viz. maximum fresh weight (37.76g) and dry weight(7.32g) of roots, root volume (45.55 cubic centimeter), number of thin (190.55) and thick (176.11) roots and root length (28.22cm) was recorded in the treatment M_3T_0 : Black polythene+Open field. However, root: shoot ratio was observed maximum (0.46) in the treatment M_1T_0 : Rice husk+Open field.

With respect to soil parameters, maximum recorded value of pH (7.49) and minimum EC (0.35dSm^{-1}) was found in the treatment M_3T_0 : Black polythene+Open field. Treatment M_1T_1 : Rice husk+Agro shade net had maximum OC (0.76 per cent), available N (734 kg ha^{-1}) and water holding capacity (53.90 per cent). Available P (58.13 kg ha^{-1}) and available K (513 kg ha^{-1}) were recorded maximum in the treatment M_1T_2 : Rice husk+Naturally ventilated polyhouse and M_3T_2 : Black polythene+Naturally ventilated polyhouse respectively.

Based on overall performance, treatment M_3T_0 : Black polythene+Open field was found superior over all other treatments with respect to growth, production, quality and root growth parameters of strawberry.

* P.G. Scholar, Department of Fruit Science, CHF, Jhalrapatan, Jhalawar- 326 023 (Rajasthan)

** Professor, Department of Fruit Science, CHF, Jhalrapatan, Jhalawar-326 023(Rajasthan)

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The cultivated strawberry (*Fragaria x ananassa* Duch.), a hybrid of two native American species; *F. chiloensis* and *F. virginiana*, was first developed in France in the 17th century. It grows well under temperate climate but can also be grown in tropical and sub-tropical climates. It is also grown widely in European countries, Israel, Japan, Turkey, Australia and New Zealand. The United States is the world's largest producer of strawberries accounting for about 30 percent of the world strawberry production (Morgan, 2012).

Strawberry (*Fragaria x ananassa* Duch.) is one of the most delicious, attractive, nutritious and refreshing soft fruits of the world. The plant is herbaceous plant comprising of fibrous roots, rosette short crown attached with bunched trifoliate leaf with long petiole and the runner producing shoots (Fig.1). Strawberry belongs to the family Rosaceae and its cultivated varieties are octaploid ($2n=56$) in nature. Botanically, the strawberry fruit is an aggregate fruit which are highly perishable (Finn and Strike, 2008). They are widely acclaimed for pleasant flavour, conspicuous colour and varied blend of taste. Delicacy of flavour, richness in vitamins and minerals makes strawberry a food in the diet of millions of people around the globe (Bhat *et al.*, 2005).

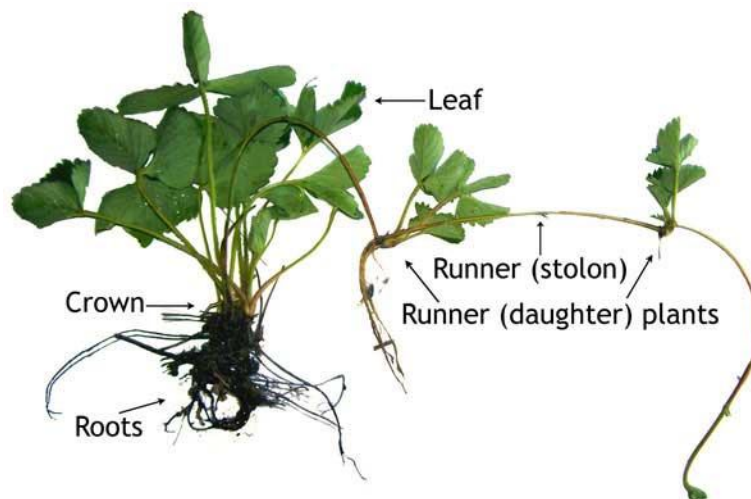


Fig. 1 Morphology of strawberry plant

Owing to its medicinal properties (anticarcinogenic, antidiabetic and antioxidant), strawberry is gaining popularity among all age group consumers. Strawberries are good source of natural anti-oxidant (Wang *et al.*, 1996, Heinonen *et al.*, 1998) including carotenoids, vitamins, phenols, flavonoids, dietary glutathione and metabolites (Larson, 1988) and exhibit a high level of anti-oxidant capacity against various group of free radicals such as superoxide, hydrogen peroxide, hydroxyl radicals and singlet oxygen (Wang and Jiao, 2000). Strawberry's antioxidant activity levels are affected not only by the genotype but also by both growing temperatures (Wang and Zheng, 2001) and cultural practices (Wang *et al.*, 2002).

Lower calorific value, absence of cholesterol and higher level of phosphorus, potassium, calcium, iron, vitamin C (40-100mg/100g berries) (Kumar *et al.*, 2011), vitamin-B and proteins, further makes strawberry ideal for health conscious consumers. It is in high demand for table purpose as well as jam making, canning, ice-cream preparations, beverages, wine, soft drinks and other quality products. Strawberry is a complete fruit with 98 per cent edible portion. Among the fruits, it gives quickest returns in shortest possible time.

In India, it is mainly grown in Maharashtra and in hills of Himachal Pradesh, J&K, Uttarakhand, Maharashtra (Rana and Chandel, 2003). The Panchgini-Mahabaleshwar region of Maharashtra grows more than 85 percent of country's strawberries. Presently, a number of varieties are grown for commercial cultivation in different regions of India out of which Sweet Charlie, Festival, Camrosa, Belrubi, Winter Dawn, Senga Sengana, Chandler, Gorella, Douglas, Ofra, Phenomenol, Selva, Red Coat, Torrey, Pajero, Confectura, etc. are notable among them.

According to response of varieties to photoperiod, there are two types of strawberry i.e. day neutral and short day plant. Long day (ever bearing) plants are also available but they are rarely grown outside home garden. Short day type cultivars are actually facultative short day plants which initiate flower under short day conditions (less than 14hrs. of day length). The temperature and day-length (photoperiodism) have the considerable effect on growth and yield of the

strawberry probably through the control of the production of plant hormones. An average growing temperature of 15°C has been reported ideal for most of the strawberry cultivars and species. However, they grow well at a temperature range between 20°C and 26°C. It has been observed that high growth rates in strawberries are maintained at day temperatures of 22-23°C.

Strawberry being a surface feeder requires optimum moisture and temperature conditions especially in the upper layer of the soil. These conditions have great influence on sustainable growth and development of the crop. In light soils, frequent irrigation is required for proper establishment of the runner and to maintain good size of berry and also quality of fruit. It prefers slight acidic soils with a pH of 5.8-6.5. Mulches have their impact in making crop sphere amenable to plant.

Strawberry, as the name indicates, being delicate in nature requires litter material for its successful cultivation and clean production. The fruits of strawberry rest on ground surface and are easily attacked by soil borne pathogens which cause rotting of fruits. To prevent this kind of rot, litter material is used which is popularly known as mulch and the practice of its application is known as mulching. Mulching is a practice of covering the surface of soil with loose extraneous materials. It reduces evaporation and moderates wide fluctuations in diurnal soil temperature especially in the root zone environment. Though, it cut-off solar radiation falling on the ground but being an insulating agent, mulched soils are warmer in winter and cooler in summer. It also suppresses weed-flora and reduces weed competition with crop for water and nutrients which get available in greater quantities to crop plants. Moreover, the practice of mulching helps in increasing downward movement of water and its percolation deep in the soil profiles escaping evaporation due to reduction in thermal gradients and exchange of vapours. Investigation on impact of different mulching materials on growth, yield and quality has indicated that strawberry is very responsive to the different mulching materials. They have strong influence on yield, quality and duration of harvesting, which is primarily due to better soil and moisture conservation, changes in soil temperature, improved nutrient availability, suppression of weed, protection from frost injury and reduction in number of

dirty and diseased berries (Sharma and Singh 1999, Sharma *et al.* 2001, Sharma 2002). The yield of berries may increase in winter plantations with clear plastic mulch up to 70 percent or more compared to no mulch (Voth, 1972), which is primarily due to rise in soil temperature and better plant growth and health under mulch. Strawberry (*Tioga*) yield increased by 68 percent and 33 percent when plants were mulched with clear plastic and pine needles over control (Badiyala and Aggrawal, 1981).

Under Rajasthan condition, strawberry is grown during post-monsoon mostly under polyhouse conditions and to some extent under open conditions. The plant remains in cultivation during winter when temperature sometimes dips down exceedingly. If it goes down to 10°C, the growth and production are badly affected. Mulching with vested attributes of temperature buffering seems promising in mitigating the ill effect of low temperature during winter. It holds special significance for cultivation of strawberry outside polyhouse conditions. Strawberry is one of the crops that respond well to the increase in soil temperature/light reflectance produced with the use of mulches (Sonkaret *al.*, 2012). Mulches are likely to optimize growing condition and also to the input use. Keeping the knowledge gaps in view and considering the utility of such a study, the present investigation entitled, “**Effect of mulches on growth, production and quality of Strawberry (*Fragaria x ananassa*Duch.) cv. Winter Dawn under different growing environments**” was carried out with the under-mentioned objectives:

1. To study the effect of mulches on growth parameters of plants
2. To study the effect of mulches on production parameters of plants
3. To study the effect of mulches on quality parameters of plants
4. To study the effect of mulches on soil environment of plants grown in different environments and its correlation with growth, production and quality parameters of fruits.

The chapter is an attempt to present comprehensive information on the growth and production of strawberry with the use of mulches under different environment conditions. Various workers have attempted cultivation of strawberry using different kind of mulches under different growing environments. To take an account of relevant work undergone in this line suiting to the objective of present study, various available and updated literatures have been gone through. The cohesive and comprehensive findings quoted there from have been presented under various heads as per context as under:

Soil parameters

Neuweiler (1997) found improved nitrogen availability in strawberry grown in soil mulched with black polythene than those under uncovered control.

Herms *et al.* (1999) also observed that mulching with composted yard waste dramatically increased total soil N as well as N mineralization rate in River Birch.

Sharma and Acharya (2000) in field crops observed that mulch maintains soil moisture at higher levels as compared with unmulched soil.

Abu-Bakr and Mustafa (2003) reported that plastic mulches conserved soil moisture in Okra field as compared to bare plots.

Singh *et al.* (2005) found that black polythene retained higher soil moisture content in tomato planted during December in open field.

Singh *et al.* (2006a) reported that polythene mulch retained 55 percent moisture in upper 15 cm soil layer in brinjal field whereas, organic mulch retained only 36 percent moisture in comparison.

Chauhan and Shylla (2006) in an experiment on plum concluded that black polythene mulch recorded significantly higher soil moisture content at both depths (0-22.5 cm and 22.5-45 cm) while clean cultivation recorded the minimum soil moisture content.

Awodoyinet *et al.* (2007) studied effect of mulches on tomato and reported that mulches are effective in conservation of soil moisture. Moisture loss was least under plastic mulch and highest on the unweeded plot. This view was supported by Garget *et al.* (2007) who observed that average moisture was highest under black polythene mulch (72.12percent) followed by dry grass (68.14percent) and paddy straw (68.05percent).

Pervaizet *et al.* (2009) found that wheat straw mulch improves soil physical health in maize field.

Sinkevicieneet *et al.* (2009) observed higher soil moisture content and higher amount of available P in mulched soil.

Albert *et al.* (2010) reported that plastic mulching significantly influenced the nutrient content and pH of soil in blueberry field.

Das *et al.* (2012b) observed that both rice husk and black polythene mulches could perform well in arresting nitrogen loss in soil profile and ensuring its availability to crop for a longer period of time.

Kumar and Dey (2012) reported that soil moisture content in strawberry field increased by 2.8-12.8 percent due to black polythene mulch under sub-temperate conditions.

Bajorieneet *et al.* (2013) evaluated the effect of different organic mulches with different thickness on the content of soil organic carbon and observed that straw mulch when applied as thick layer significantly increased the soil organic carbon content.

Kimiti and Gordon (2013) in an experiment in barley field observed that pH of soil decreases with the application of mulch (leaf mulch) within the first four weeks. Placing mulches on the soil surface also resulted to a gradual nitrate release.

Singh *et al.* (2013) reported that under FYM mulch the N, P and K status was higher by 363, 392 and 275percent over control in brinjal field. Nutrient removal of crops, in general, was significantly higher under FYM mulch over all other treatments.

Mahadeen (2014) reported higher soil moisture content in mulched plot as compared to bare soil plots in summer vegetable crop.

Taparauskiene and Miseckaite (2014) in an experiment on strawberry revealed that highest average weight-based soil moisture content of active soil layer (0-40cm) was 18 percent in the field mulched with straw while lowest one, 16.2 percent in the field without mulching; in the plot mulched with black polythene it was 16.5 percent.

Soil and Environmental temperature parameters

Draper *et al.* (1981) reported that fruit size becomes smaller with increase in temperature in strawberry.

Galletta *et al.* (1981) suggested that 10°C drop in soil temperature would increase the fruit size by 0.9-1.6 g in strawberry.

Noguchi and Yamakawa (1988) also reported that fruit size becomes smaller in strawberry with increase in temperature.

Hellman and Travis (1988) reported that high soil and environmental temperature reduces vegetative and root growth in strawberry.

Decoteau *et al.* (1989) reported that in tomato field soil temperature was high under black polythene mulch, and further observed that dark colored plastic mulches have higher soil surface temperature than white mulch.

Lamont (1993) mentioned that improvement in soil temperature under black films attributed to the reduction in heat loss.

Kumakura and Shishido (1994) also reported that fruit size of strawberry becomes smaller with increase in temperature.

Miura *et al.* (1994) in strawberry observed decreased fruit size with increase in temperature.

Fortnum *et al.* (1995) observed greater soil temperature under black and red mulch than under white mulch.

Neuweiler (1997) found improved soil temperature with black polythene mulching than uncovered control.

Mori (1998) in strawberry reported that fruit size become smaller with increase in temperature.

Wang and Camp (2000) observed decreased fruit size in strawberry with increase in temperature.

Diaz-Perez and Batal (2002) observed that root zone temperature influences vegetative top fresh weight, fruit yield, fruit number and individual fruit weight of tomato. They reported increased root growth with increase in soil temperature.

Abu-Bakr and Mustafa(2003) reported that plastic mulches significantly improved soil temperature in Okra but clear transparent plastic mulch was superior over black opaque mulch with respect to soil temperature.

Dupponget *al.* (2004) observed that crop residues overspread on soil surfaces decrease soil temperature in the hot season and maintain it in autumn.

Diaz-Perez *et al.* (2005) in an experiment with tomatillo observed that mean root zone temperature was highest under black mulch and lowest in bare soil.

Locascio *et al.* (2005) in an experiment on strawberry observed higher soil temperature under the black polythene mulch.

Singh *et al.*(2006a) reported that mulches were found to be more effective in moderating the soil temperature than control.

Singh *et al.* (2005) reported that black polythene retained higher soil temperature in the soil of tomato planted during December in open field.

Chauhan and Shylla (2006) in an experiment on plum observed maximum soil temperature under black polythene mulch while minimum was recorded in hay mulch.

Ghosh *et al.* (2006) in an experiment on groundnut observed an increase of 4-5°C soil temperature in polythene mulch throughout the cropping season.

Ramkrishna *et al.* (2006) studied the effect of mulch on soil temperature on groundnut and reported that different mulching materials showed different impact on soil temperature.

Polythene mulch increased the soil temperature by about 6°C at 5cm depth and by 4°C at 10cm depth.

Yang *et al.* (2006) observed that plastic film mulch increased soil temperature as compared to straw and concrete mulch. Straw mulch decreased soil temperature.

Awodoyinet *al.* (2007) observed effectiveness of plant based mulches in reducing soil temperature.

Diaz-Perez *et al.* (2007) studied the effect of mulches on tomato and observed that root zone temperature was highest under black mulch followed by gray, silver and white mulch.

Karhuet *al.* (2007) found that black polythene improved the soil temperature in strawberry.

Ochmianet *al.* (2007) studied the effects of mulching with black and white polythene films and black non-woven polypropylene and observed that mulching with a black polythene film increased soil temperature by 4°C in comparison to the control.

Ledesma *et al.* (2008) reported that fruit size become smaller and fruit number decreases with increase in temperature from 18-23°C to 25-30°C

Diaz-Perez (2009) studied the effect of coloured plastic mulches on root zone temperature in broccoli and observed highest root zone temperature in dark coloured mulches (blue, black, red and gray) and lowest in light coloured mulches (silver and white).

Ekinci and Dursun (2009) found that soil temperature in clear and black mulch applications were higher (5-8°C and 1-4°C, respectively) than that of control.

Sinkevicieneet *al.* (2009) observed decreased soil temperature in mulched soil as compared to unmulched soil.

Abd El-Kader *et al.* (2010) in an experiment observed that there was more increase in soil temperature under blue polythene mulch. They recorded that soil surface temperature was lowest under rice straw.

Josuitiset *al.* (2011) observed decreased fruit size with increase in temperature in strawberry.

Kamal and Singh (2011) evaluated the effect of soil mulching with black plastic sheets on soil temperature for tomato and observed highest soil temperature under black plastic mulch during early growth season due to less shade on the surface.

Rajablarianiet *al.* (2012) found that soil temperature increased under the various colored plastic mulches about 3 to 6°C more than in bare soil.

Singh *et al.* (2012a) observed that rhizosphere temperature at 20 cm depth in polytunnel was higher by 2.64°C, 2.23°C and 1.82°C compared to 75 percent shade, 50 percent shade and open field, respectively. About 2-6 percent higher relative humidity was observed during the whole growing period inside different low tunnel structures compared to open field.

Growth parameters

Kirnaket *al.* (2001) investigated the effectiveness of different mulches on plant growth parameters in strawberry and found that black polythene mulch and wheat straw mulch improved the plant dry matter, leaf area index, and chlorophyll content in leaves.

Kesikand Maskalaniec(2003) reported from Vilnius Region in Lithuania that strawberries (cv. SengaSengana) when grown using black plastic foil had the more number of leaves than soil mulching with rye straw and wood bark.

Sharma and Sharma (2003) concluded that black polythene mulch favoured better plant growth in strawberry, but enhanced the incidence of albinism in a sub-tropical climate when compared with paddy straw. Thus, paddy straw is the best option for use as mulch for strawberry in warmer localities.

Sharma *et al.* (2003) evaluated the effect of various mulches on plant growth of strawberry and observed highest plant height, leaf number and chlorophyll content with black polythene mulch and minimum with paddy straw mulch.

Larson *et al.* (2004) conducted an experiment to determine the effect of mulch on plant growth of strawberry and found that plant canopy, vegetative growth and shoot to root dry mass ratio were greatest for clear full bed mulch as compared to other mulch treatments viz. clear center-strip (CS), full yellow-on-black (YB) and full bed green (GR) polythene mulches.

Mathad and Jholgiker (2005) reported the efficacy of organic and synthetic mulches on the performance of strawberry cv. Chandler under mild sub-tropical ecosystem of Karnataka. The strawberry plants covered with polythene mulches were more vigorous compared to rice straw and coir pith mulches. Initially, the transparent polythene mulches promoted plant height and spread, however, in the later critical stages of growth, the plants covered with W/B laminated polythene mulch produced more proliferated growth as depicted by higher plant spread and leaf area at 240 days after planting.

Singh and Asrey (2005) observed that under Delhi condition, strawberry cv. Chandler when planting in mid-September with black polythene enhanced plant growth.

Studies conducted to see the effects of planting time and mulching on the growth, flowering, fruiting behaviour, yield and quality of strawberry cv. Chandler by Singh *et al.* (2005) revealed that mid-September planting and mulching with black polythene favoured vigorous growth.

Berglund *et al.* (2006) in strawberry found that mulching with degradable plastic resulted in increased number of runners and produced healthier plants during the autumn.

Ghosh *et al.* (2006) reported that rice straw mulch produced 16percent more plant biomass of irrigated groundnut than polythene mulch (white and black) and control. They also reported better plant growth under straw mulch due to increased soil water content and moderate soil temperature.

Pireset *al.* (2006) performed an experiment to evaluate the effect of soil mulches for different cultivation environments and found that in protected cultivation under clear plastic mulch there is increase in height and spread of strawberry.

Sharma and Khokhar (2006) found that black polythene mulch significantly increased plant height (23.39 and 25.53 cm), number of leaves (23.67 and 25.00) and number of runners (17.67 and 19.33) followed by bicoloured polythene mulch, grass mulch and pine needles of strawberry cv. Chandler.

Ali and Gaur (2007) reported that mulching increased the vegetative growth and flowering of strawberry cv. Sweet Charlie at Kanpur. Plants mulched with black polythene showed the maximum plant height, plant spread, number of leaves and flowers.

Ambadet *et al.* (2007) reported that growing condition of low tunnel with mulch recorded maximum plant spread (31.01 cm) in strawberry cv. Chandler.

Karhuet *et al.* (2007) found that black polythene reduced the chlorophyll content in strawberry leaves whereas white polythene favored crown growth.

Singh *et al.* (2007) observed that cv. Chandler planted during mid-September produced maximum plant growth.

Waniet *et al.* (2007) reported that strawberry cv. Confitura planted in November and mulched with black polythene exhibited the best growth.

Katiyaret *et al.* (2009) observed the effect of mulching on plant growth, yield and quality of strawberry under Kanpur agro-climatic conditions. They found that crown height and spread, leaf number and leaf area were influenced by different mulch materials. Black polythene established its superiority with regard to maximum crown height, crown spread, leaf number, leaf area followed by white polythene and paddy straw.

Studies of Kaur and Singh (2009) from the experiment using different type of mulch (black polythene, transparent polythene, paddy straw, saw dust, dry grasses and unmulched control) reported maximum number of leaves in black polythene mulched plants of strawberry cv. Chandler followed by transparent polythene and paddy straw.

Sharma (2009) reported that under silty clay-loam soil black polythene mulching and 15 cm row spacing produced the highest crown height (11.1 cm), plant spread (22 cm) and leaf area (85.8 cm²) in strawberry cv. Tioga.

Kheret *et al.* (2010) observed that 9th October planting coupled with black polythene mulching was most favorable for successful cultivation of strawberry under sub-tropical conditions of Jammu. Plant height (20.86 cm), plant spread (30.00 cm) and leaf area (64.76 cm²) were significantly higher in plants mulched with black polythene than those either mulched with transparent polythene or paddy straw. The interaction effect of planting time and mulching material was found significant in case of number of crowns per plant (0.37) and number of runners per plant (0.15).

Ashrafuzzaman *et al.* (2011) in an experiment on chilli observed increased plant height, number of primary branches and number of leaves on plastic mulch. Mulching produced the fruits with highest chlorophyll-a, chlorophyll-b and total chlorophyll content.

Sheng *et al.* (2011) noticed decreased chlorophyll content under polyhouse conditions in strawberry in South China.

Singh and Dwivedi (2011) observed that strawberry cv. Chandler performed best for most of the vegetative characters viz. plant height, number of leaves, plant spread (East-West and North-South) and number of runners under yellow and black polythene mulch followed by white polythene, green shade net, transparent polythene, dry grass mulch and control.

Kumar *et al.* (2012a) found that strawberry cv. Chandler which was grown under different mulches and irrigation levels showed significant response on plant growth parameters like, crown height, plant spread and leaf area.

Kumar *et al.* (2012b) in an experiment observed that clear polythene gave the best results in terms of plant height (21.10cm), plant spread (28.99cm), petiole length (26.10cm) and leaf per plant (11.77) of strawberry cv. Sweet Charlie.

Prasad *et al.* (2012) observed positive combined effect of black polythene mulch on plant growth in Douglas cultivar of strawberry at Ranchi in open field.

Qureshi *et al.* (2012) evaluated the impact of cultivation systems on growth and yield of strawberry (*Fragaria ananassa*) cv. "Chandler" and observed maximum plant height, crown size, number of leaves and dry weight of leaves under tunnel condition as compared to other cultivation system (greenhouse and open field).

Pop *et al.* (2013) reported that black polythene produced maximum number of runners than other mulches (white and straw).

Production parameters

Kozłowski and Kropisz (1992) visualized the positive impact of mulching on fruit yield in strawberry.

Gupta and Acharya (1993) reported increased yield, fruit weight and dimension in strawberry due to black polythene mulch.

Cortez *et al.* (1995) found that black polythene mulching was effective in reducing the quantity of unmarketable fruit by about 40 percent. They also concluded that due to higher soil temperature (thermal equilibrium) in black polythene, the fruit yield was also improved slightly.

Neuweiler (1998) found that bed covering with white plastic sheet brought early floriferous condition and improved fruit set, total yield and fruit size in strawberry than black sheets in Switzerland.

Hassan *et al.* (2000) reported that strawberry plants, under Hisar conditions, mulched with black polythene produced the highest yield, followed by those mulched with transparent polythene and *Saccharum* residues. The lowest yield was obtained in the control.

Highest total and marketable yields in the first three years with plastic mulch and in fourth year by bark mulching in cultivars 'Korona', 'Nora' and 'Jonsok' was recorded by Birkeland *et al.* (2002). They found that straw mulch performed well in the first year of harvest with higher yields than bark mulch and the lowest number of fruits infected by *Botrytis cineraria*. Plastic mulch promoted fruit ripening whereas straw mulch delayed ripening.

Kikasand Luik (2002) recommended that the black plastic and the bed carpet mulches was the best for strawberry plants because these materials promoted strawberry yield and beneficial insects in strawberry beds.

Plekhanova and Petrova (2002) established that mulching accelerated the beginning of flowering and ripening for 1 to 7 days, increased yield for 20 per cent on the average at the expense of the larger number of peduncles and berries.

Kesik and Maskalaniec (2003) observed that mean number of inflorescences was highest in plants from the black foil mulches, and lowest in plants from the rye straw and wood bark mulches. Among the studied mulches, black foil had the best positive effect on the rate of fruit setting.

Larson *et al.* (2004) observed increased fruit size and greater yield under clear full bed mulch in strawberry cv. Commander.

Moor *et al.* (2004) found that fertilizer application had a positive effect on the yield of first grade fruits with plastic and straw mulch.

Kumar *et al.* (2005) in strawberry found that grass mulch was effective in increasing the fruit size, whereas, black polythene in improving the yield level over other treatments.

Sharma *et al.* (2005) found significantly higher berry yield under drip irrigation at 100 percent evaporation + black polythene mulch (78.6 q/ha) in cv. Chandler, whereas, the lowest yields (12.13 q/ha) was recorded in non-irrigated treatment (rainfed + unmulched control).

Singh and Asrey (2005) under Delhi condition observed that mid-September planting resulted early flowering (77.3 days) and fruiting (33.0 days) and greater fruit weight (13.0 g), early yield (1489 g/m²) and total fruit yield (2791 g/m²) than other planting dates. Plants mulched with black polythene resulted in earlier flowering (80.2 days) and fruiting (29.2 days) and larger fruits (12.8 g) than clear polythene or rice straw. Fruit yield was significantly higher in plants mulched with black polythene (2758 g/m²), which was higher by 24.2 and 17.8 percent than the yields of plants mulched with clear polythene and rice straw, respectively.

Pireset *et al.* (2006) reported that clear plastic mulch favoured total marketable yield and its components (number and weight of fruit per plant) in protected cultivation (even-span greenhouse) of strawberry.

Sharma and Khokhar (2006) found that strawberry cv. Chandler grown on black polythene mulch produced significantly higher yield having large size fruits.

Singh *et al.* (2006b) reported that black polythene was found to be the most suitable for strawberry which produced 41 percent higher fruit yield when compared with straw mulch.

Ali and Gaur (2007) reported that mulching increased the flowering of strawberry cv. Sweet Charlie at Kanpur. Plants mulched with black polythene showed the maximum number of flowers, number of fruits per plant, average weight, size and fruit yield.

Ambadet *et al.* (2007) reported that growing condition of low tunnel with mulch recorded earliest 50 percent flowering (57 days), number of fruits per plant (19.28), average size of fruit

(3.43 cm), weight of fruit (10.19 g), yield per square meter (1.18 kg) and per hectare (11.84 t) in cultivar Chandler.

Singh *et al.* (2007) observed that cv. 'Chandler' when planted during mid-September enhanced flowering (77.3 days) which resulted in production of significantly larger fruit (13.0 g) and higher yield (174.4 g/plant) with lesser incidence of albinism (9.6 percent) and botrytis rot (8.1 percent) than other plantings. Plants mulched with black polythene showed early fruit set (29.2 days) and produced larger fruit (12.6 g) and higher yield (172.4 g/plant) with slightly higher incidence of albinism (20.1 percent, but lower incidence of botrytis rot (7.3 percent) than those mulched either with clear polythene or paddy straw.

Castaneda *et al.* (2009) reported the black polythene film (30 microns) used as the control, gave the highest strawberry production followed by the black polypropylene (TNT or non-woven) in cultivars 'Oso Grande', 'Aromas' and 'Camrosa'. 'Camrosa' when planted using mulch of polythene film produced more fruits per plant (386.66 g) and more fruits per unit area (19.33 tons ha⁻¹). They finally concluded that, even though, polythene film showed better results, the black TNT was promising due to higher fruit weight.

Ekinci and Dursun (2009) in an experiment found that average fruit weight of the cultivars was significantly high in mulch application, especially with clear mulch application as compared to control. Average marketable yield in the study years increased by 25-28 percent in clear plastic mulch and 15 percent in black plastic mulch as compared to the control application.

Fracet *et al.* (2009) evaluated the effect of mulches on yield and size of strawberry cultivars and found that plants of the cv. Elsantawhen mulched with compost or saw dust produced fruit with greater mean weight (by an average of 1.5g) as compared to control. Mulched plots also produced more number of fruits in the cv. Ekstra.

Studies of Kaur and Singh (2009) while studying on mulches (black polythene, transparent polythene, paddy straw, saw dust, dry grasses and unmulched control) reported maximum number of flowers, fruits and fruit yield in black polythene mulched plants of cv. Chandler followed by transparent polythene and paddy straw.

Kolheet *et al.* (2009) reported that grass mulch and black polythene mulch was effective in increasing fruit weight and number of fruits per plant in muskmelon under polyhouse conditions, whereas, shade net was not effective.

Larson *et al.* (2009) determined yield performance of 'Camrosa' and 'Ventana' cultivars under open field (OF) and protected culture (PC; i.e., Spanish tunnel) production in southern California. Yield performance of plants grown on black and clear polythene bed mulches (PBM) was determined in both production systems, and PAR (photosynthetically active radiation), UV transmissibility and yield performance were compared using two different tunnel films. Results demonstrated increased yield and fruit quality in California strawberries under protected culture.

Sharma (2009) under silty clay-loam soil black polythene mulching and 15 cm row spacing reported highest fruit set, fruit weight (10.1 g), fruit length (3.7 cm), fruit diameter (2.4 cm) and fruit yield (2.62 t/ha) in strawberry cv. Tioga.

Kheret *et al.* (2010) observed higher fruit weight (14.69 g) and fruit yield (295.78 g) of strawberry under black polythene mulch than those in transparent polythene or paddy straw mulch. The interaction effect of planting time and mulching material was found significant in case of fruit yield (27.33) per plant.

Agueoet *et al.* (2012) evaluated strawberry cultivars for its suitability to sugarcane (*Saccharumofficinarum* L.) harvest residue as an alternative to plastic mulch. They reported that during months with less than 20°C average daily temperature, yields were higher under plastic mulch in all cultivars, whereas, during months with more than 20°C average daily temperature, no difference in yields between mulch types were noticed. The harvest period in sugarcane harvest residue mulch started later than in plastic mulch, but harvest season was more extended towards the end of cycle.

Das *et al.* (2012a) conducted an experiment at high altitude temperate climate and observed that under greenhouse condition fruit yield ranged from 110.0 to 126.6 g/plant in strawberry cv. Camrosa, Blakemore, Chandler, Gorella and Oso Grande. Days from full bloom to harvest were reduced to 30.4 days in comparison to 36.8 days under open conditions. Cultivars under low polytunnels also performed better, with a yield range of 81.6 to 100.6 g/plant and took only 32.1 days from full bloom to harvest.

Kumar and Dey (2012) observed five times higher fruit set and five times higher fruit yield with black polythene mulch coupled with drip irrigation.

Prasad *et al.*(2012) observed positive effect of black polythene mulch on fruit yield, maturity and benefit:cost ratio in Douglas cultivar of strawberry at Ranchi in open field.

Qureshi *et al.* (2012) observed higher number of flowers, fruits, increased fruit size and weight in tunnel condition as compared to other cultivation systems (greenhouse and open field) of strawberry cv. Chandler.

Singh *et al.* (2012a) found that the period of fruit availability of strawberry was extended to 47 days from normal period and highest yield with firm fruits were obtained from plants grown under UVS polythene cover.

Singh *et al.* (2012b) in another field trial on strawberry found that drip irrigation with polythene mulch gave significantly highest yield (50.10 q ha⁻¹) as compared to surface irrigation in an unmulched condition (40.15 q ha⁻¹).

Yuri *et al.* (2012) observed that the black and the silvercolour plastic mulches were effective in yield increase when it was installed before seedling transplanting in strawberry.

Hughes *et al.* (2013) reported that strawberry plants grown on the black and black-on-white mulches produced greater total and marketable yields than those on the white-on-black and silver-on-black mulches in the cooler climate of New Liskeard. During the first picking year in the high tunnel, the greatest total and marketable yields of 'Albion' were obtained from the white-on-black and silver-on-black mulch treatments.

Pop *et al.* (2013) reported that black and white polythene mulch produced higher fruit yield in comparison to unmulched control plant of strawberry.

Wallace and Webb (2013) observed that high tunnel strawberries were harvested for six to eight weeks longer than those in the open field.

Bakshiet *al.*(2014) found that strawberry is very much responsive to mulching and ground cover and black polythene is highly effective for increased flowering, fruiting, fruit weight, size and yield.

Taparauskiene and Miseckaite (2014) evaluated the effect of mulches on strawberry and found that the yield gained from the field mulched with the black polythene was higher by 60 percent than that in the non-mulched field and by 56 percent in comparison to the yield in the plot mulched with straw.

Quality parameters

Gupta and Acharya (1993) reported increased TSS, sugar and lower acidity in strawberry due to black polythene mulch.

Sharma and Khokhar (2006) found that strawberry cv. Chandler grown on black polythene mulch produced fruits with lower acidity and higher TSS, sugar, ascorbic acid and anthocyanin content.

Hassan *et al.* (2000) from Hisar reported that strawberry plants mulched with black polythene produced highest quality fruits.

Moor *et al.* (2004) found that fertilizer application had a positive effect on the yield of first grade fruits with both plastic and straw mulches. With plastic mulch, fertilizer application had a positive influence on vitamin C content.

Kumar *et al.* (2005) found that grass mulch was effective in increasing the sugar content, TSS/ acid ratio and anthocyanin content in strawberry.

Moor *et al.* (2005) from Estonia, reported that straw mulch had significantly negative influence on the content of anthocyanin in strawberry fruits. Strawberry fruits grown with plastic mulch also contained more vitamin C than those grown with straw mulch.

Das *et al.* (2007) evaluated 33 promising strawberry genotypes with different mulching materials (black polythene, paddy straw and Deenanath (*Pennisetum pedicellatum*) under sub-humid subtropical plateau region of eastern India. Irrespective of types of mulches, the average of total soluble solids (TSS) on different mulches ranged from 6.78°B (Florida) to Phenomenal and No-1 (11.48°B).

Singh *et al.* (2007) observed that cv. 'Chandler' showed best quality parameters like higher TSS (9.41 percent), acidity (1.17 percent) and ascorbic acid content (46.4 mg/100 g pulp) when planted during mid-September and mulched with black polythene.

Katiyar *et al.* (2009) observed the effect of mulching on plant growth, yield and quality of strawberry under Kanpur agro-climatic conditions and found that quality traits (TSS, sugar and vitamin 'C') of fruit were influenced by different mulch materials. Black polythene established its superiority with regard to quality parameters followed by white polythene and paddy straw.

Kaur and Singh (2009) recorded highest TSS, sugar percentage and ascorbic acid percentage in black polythene mulched plants of cv. Chandler followed by those mulched with transparent polythene and paddy straw.

Gantait and Pal (2010) observed non-significantly higher content of anthocyanin in chrysanthemum under polyhouse condition.

Singh *et al.* (2010) observed higher ascorbic acid in capsicum grown under polyhouse than open field.

Ashrafuzzaman *et al.* (2011) evaluated the effect of coloured plastic mulch on chilli and found highest vit.C content at mature green stage on black polythene mulch.

Posada *et al.* (2011) studied the effect of coloured plastic mulches on fruit quality of strawberry and observed that silver mulch gave the lowest TSS/acid ratio while black mulch gave the highest TSS/acid ratio.

Sheng *et al.* (2011) noticed decreased soluble sugars under polyhouse conditions in strawberry in South China.

Fan Li Roux *et al.* (2012) observed plastic mulch with row cover (PMRC) better growing system, improving fruit quality and increasing the nutritional value of all genotypes.

Qureshi *et al.* (2012) evaluated the impact of cultivation systems on growth and yield of strawberry (*Fragaria ananassa*) cv. "Chandler" and found that TSS, total sugars and ascorbic acid were found significantly higher under tunnel condition as compared to other growing condition viz. greenhouse and open field.

Singh *et al.* (2012a) while assessing the influence of microclimate changes caused by low tunnels in strawberry found higher ascorbic acid and anthocyanin content under UVS polythene which was at par with the plants planted under 50 percent shade.

Yuri *et al.* (2012) observed that the black and the silver colour plastic mulches has been effective in better fruit development in strawberry when it was installed before seedling transplanting.

Pop *et al.* (2013) reported that straw mulch produced lowest sugars content in strawberry fruits which was highest in black polythene mulch.

Bakshiet *al.*(2014) in an experiment observed improved TSS, sugars, vitamin C and crude protein in strawberry cv. Chandler.

Root growth parameters

Wien *et al.* (1993) observed that polythene mulch stimulated tomato root extension shortly after transplanting. One week after transplanting, roots were significantly longer for mulched than for unmulched plants.

Parmar and Sharma (1998) observed increased root weight and root volume with the use of polythene mulch in wheat.

Niuet *al.* (2004) reported that the use of plastic mulches promoted root development and increased root biomass production at different growth stages in wheat.

Vermaet *al.* (2005) reported that straw mulch was effective to increase Root Mass Density (RMD), root volume, root length density and early crop harvest in pea and tomato under sandy loam soil conditions.

Singh *et al.* (2006a) observed increased root growth in brinjal under black polythene mulch.

Karhuet *al.* (2007) observed increased root growth under white polythene mulch in strawberry.

Sandal *et al.* (2007) in an experiment on Okra found that mulches at the recede of monsoon (end of September) improved hydrothermal properties which ultimately resulted in significantly better root growth.

Mollahet *et al.* (2009) observed maximum root length (28.00 cm) and fresh root weight (80.83 g) in the plants mulched with black polythene whereas the minimum values of these are recorded in the control in broccoli.

Kumar and Dey (2011) reported that the mulches with drip irrigation were effective in enhancing root growth (63 percent) in strawberry.

Kumar and Dey (2012) observed four times higher root growth in strawberry with black polythene mulch coupled with drip irrigation.

Singh *et al.* (2013) in an experiment on brinjal found that under FYM mulch maximum values of root length to aerial mass ratio (RL/AM) was recorded. The root length density (RLD), root weight density (RWD) and root volume (RV) were higher by 370, 392 and 198 percent, respectively under FYM mulch treatment.

Chapter- 3 MATERIAL AND METHODS

The present investigation entitled “**Effect of mulches on growth, production and quality of Strawberry (*Fragaria x ananassa* Duch) cv. Winter Dawn under different growing environments**” during the year 2013-14. The details of the experiment in respect to materials used and techniques employed for studies have been described in this chapter.

3.1 EXPERIMENTAL SITE

The present experiment was conducted at the Protected Cultivation Unit, College of Horticulture & Forestry, Jhalrapatan City, Jhalawar.

3.2 LOCATION AND CLIMATE

Jhalawar district is located at 23°4' to 24°52' N-Latitude and 75°29' to 76°56' E-Longitude in South Eastern Rajasthan. Agro-climatically, the district falls in Zone V, known as Humid South Eastern Plain. About 84.22 per cent population of the district is rural whose main occupation is agriculture. The average rainfall in the region is 954.7 mm. Maximum temperature range in the summer is 43- 48°C and minimum 1.0- 2.6°C during winter. The detail of weather variables as observed under different growing environment is presented through Table 3.1 and depicted through Figure 3.1. Major kharif crops of the district are soybean, maize and pulses. While in rabi, wheat, mustard, coriander and garlic are main crops.

3.3 SOIL CONDITION

In order to assess the physico-chemical properties of the soil at the experimental site, the soil samples were drawn randomly from different spots in the field at a depth of 0-30cm before the commencement of the experiment. A representative sample was prepared and it was subjected to mechanical, physical and chemical analyses. The detailed study of soil properties as observed is presented ahead.

3.4 EXPERIMENTAL MATERIALS

3.4.1 Plants

Winter Dawn variety was bred by Dr. Craig K Chandler and released by the University of Florida in 2005. It is a short day, early bearing cultivar with heavy yield potential. It produces numerous runners (stolons) in the summer nursery, but relatively few runners after being transplanted to the fruiting field. Primary fruits are medium conic to wedge shaped weighing 25-40 g whereas secondary and tertiary fruits are mostly short conic to oval weighing 10-25 g. Fruits are often asymmetrical, but still marketable. It has a long, lanky and open canopy.

Strawberry cv. Winter Dawn plants were procured from K F Bioplants, Pune (Maharashtra). The plants were healthy and uniform in growth and vigour. In order to assess the effect of various treatments more precisely, all the experimental plots were subjected to uniform cultural practices including fertilizer application and plant protection measures. Raised beds were prepared and different kind of mulch materials under different growing environments were used to carry out the experiment as per proposed plan.

3.5 Experimental details

3.5.1 Treatment details

3.5.1.1 Different types of mulch

- 1) M₀- Control (No mulch)
- 2) M₁- 5cm thick rice husk
- 3) M₂- 25 micron gauge white polythene
- 4) M₃- 25 micron gauge black polythene

3.5.1.2 Different types of growing environments

- 1) T₀- Control (Open field)
- 2) T₁- Agro shade net
- 3) T₂- Naturally ventilated polyhouse
- 4) T₃- Fan pad system greenhouse

3.5.1.3 Treatment combinations

- 1) M_0T_0 - No mulch (M_0) + Open field (T_0) (Control)
- 2) M_0T_1 - No mulch (M_0) + Agro shade net (T_1)
- 3) M_0T_2 -No mulch (M_0) + Naturally ventilated polyhouse (T_2)
- 4) M_0T_3 -No mulch (M_0) + Fan pad system greenhouse (T_3)
- 5) M_1T_0 -Rice husk (M_1) + Open field (T_0)
- 6) M_1T_1 - Rice husk (M_1) + Agro shade net (T_1)
- 7) M_1T_2 - Rice husk (M_1) +Naturally ventilated polyhouse(T_2)
- 8) M_1T_3 - Rice husk (M_1) + Fan pad system greenhouse(T_3)
- 9) M_2T_0 -White polythene(M_2) + Open field(T_0)
- 10) M_2T_1 -White polythene(M_2) +Agro shade net (T_1)
- 11) M_2T_2 -White polythene(M_2) +Naturally ventilated polyhouse(T_2)
- 12) M_2T_3 -White polythene(M_2) +Fan pad system greenhouse(T_3)
- 13) M_3T_0 -Black polythene(M_3) + Open field(T_0)
- 14) M_3T_1 -Black polythene(M_3) + Agro shade net(T_1)
- 15) M_3T_2 -Black polythene(M_3) + Naturally ventilated polyhouse(T_2)
- 16) M_3T_3 -Black polythene(M_3) +Fan pad system greenhouse(T_3)

3.5.2 Other details of experiment

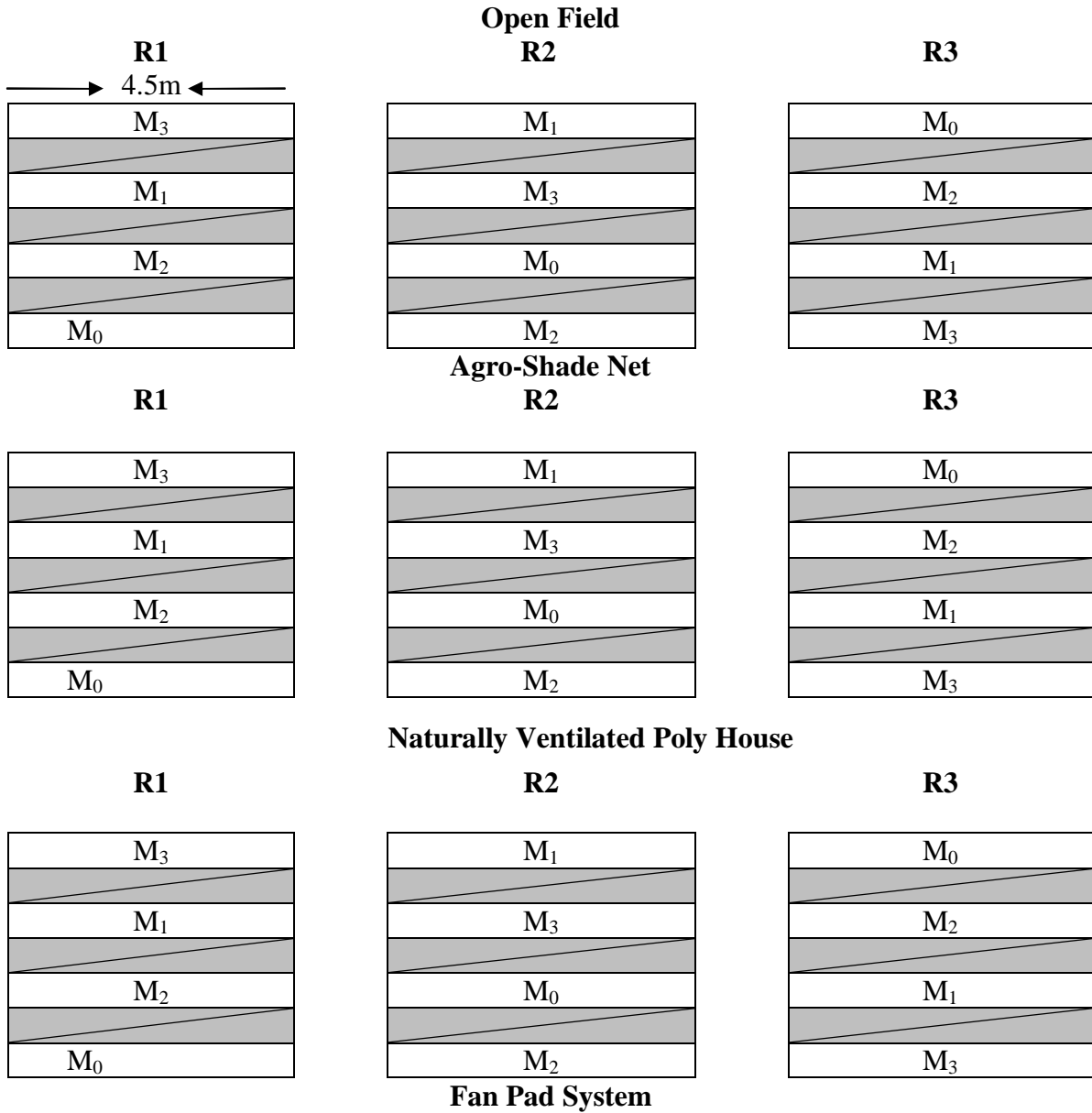
Strawberry (*Fragaria x ananassa*Duch.) cv. Winter Dawn was planted under four environments i.e. open field,Agro shade net (75 per cent intensity), Naturally ventilated polyhouse and Fan pad system greenhouse as per detail given below:

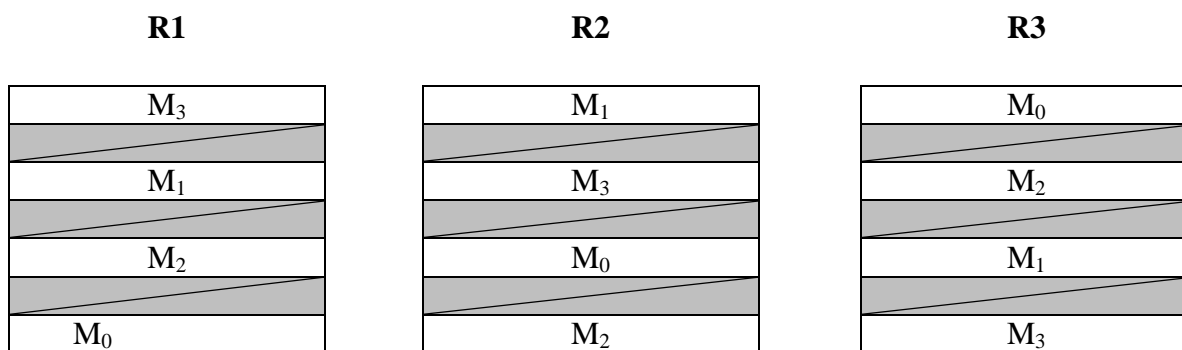
- | | |
|---|--------------------------------|
| 1. Planting system | : Raised bed |
| 2. Spacing | : 60 x 30 cm |
| 3. Total no. of treatments | : 16 |
| 4. Replications | : 3 |
| 5. Number of plants/treatment | : 3 |
| 6. Total no. of plants under study | : 144 |
| 7. Date of planting | : 4 th October 2013 |
| 8. Experimental design | : RBD |

3.6 EXPERIMENTAL LAYOUT

As per the plan of study, strawberry plants were grown overraised beds of 15cm height from ground level prepared independently under all four growing environments as in context. Between the two beds 1.0m space was left for proper intercultural operations and proper crop management. On each bed two drip lines having inline drippers at 30cm distance were stretched parallel to each other. In all, at the rate of 15 plants each row of the bed, total 30 plants were planted in a bed at 30cm spacing. Plants were planted at 10cm depth near the drippers. The detailed layout of the field is as under:

Layout of the field





Note: Each bed contains 30 Plants in double rows.

3.7 OBSERVATIONS RECORDED

To observe the effect of mulches and growing environments, various parameters were studied. The details of various observations made are as under:

3.7.1 Soil parameters (at 0-30cm depth)

A. Before experiment

1. pH
2. Electrical conductivity (dSm^{-1})
3. Organic carbon (per cent)
4. Available N (kg/ha)
5. Available P (kg/ha)
6. Available K (kg/ha)
7. Water Holding Capacity (per cent)

B. After experiment

1. pH
2. Electrical conductivity (dSm^{-1})
3. Organic carbon (per cent)
4. Available N (kg/ha)
5. Available P (kg/ha)
6. Available K (kg/ha)
7. Water Holding Capacity (per cent)

3.7.2 Soil and environmental conditions

1. Soil temperature ($^{\circ}\text{C}$) at weekly interval at 0-15 cm depth
2. Outside temperature ($^{\circ}\text{C}$) and humidity (per cent) daily morning and evening

3. Light intensity (Lux) daily morning and evening

3.7.3 Growth parameters

1. Crown height (cm)
2. Petiole length (cm)
3. Number of leaves per plant
4. Plant spread (cm)
 - East-West
 - North-South
5. Plant fresh and dry weight (g)
6. Runner production per plant
7. Total chlorophyll content of leaves (mg/g)

These parameters were recorded after final harvest of the crop.

3.7.4 Production parameters

1. Days taken to first flower initiation
2. Days taken to 50% flowering
3. Days taken to initiation of fruit set
4. Days taken to 50% fruit set
5. Days taken to first harvest
6. Days taken to final harvest
7. Number of pickings
8. Fruit length (mm)
9. Fruit width (mm)
10. Length: diameter ratio
11. Fresh weight of fruit (g)
12. Dry weight of fruit (g)
13. Number of fruits/plant
14. Fruit yield/plant

3.7.5 Quality parameters

1. TSS (°Brix)
2. Titratable acidity (per cent)
3. TSS/acid ratio

4. Sugar (per cent)
 - Total sugar
 - Reducing sugar
5. Juice (per cent)
6. Vitamin C (mg/100g)
7. Anthocyanin (mg/100g)
8. Sensory score

3.7.6 Root growth parameters

1. Root weight (g)
 - Fresh weight
 - Dry weight
2. Root volume(cc)
3. Root length(cm)
4. Number of roots
 - Thin roots (<0.20mm)
 - Thick roots (>0.20mm)
5. Root: shoot ratio

3.8 METHODOLOGY USED FOR OBSERVATIONS

3.8.1 SOIL AND ENVIRONMENTAL PARAMETERS

3.8.1.1 Soil temperature (°C)

The soil temperature of bed in each treatment from 0 to 15 cm depth was recorded at 15 days interval with the help of soil thermometer.

3.8.1.2 Temperature (°C) and humidity (per cent)

The daily outside temperature (°C) and relative humidity (per cent) from each treatment was recorded in the morning at 9.00 AM and in the evening at 3.00 PM with the help of thermohydrometer.

3.8.1.3 Light intensity (Lux)

The light intensity in each treatment was recorded daily three times a day viz. at 9.00 AM, 12.00 PM and 4.00 PM with the help of Lux meter.

3.8.2 PLANT GROWTH PARAMETERS

Three plants were selected randomly in each replication for taking observations on growth and physico-chemical parameter of fruits.

3.8.2.1 Crown height (cm)

The aerial portion of the plant constitutes crown. The crown height of the randomly selected plants was measured in each replication at final harvest with the help of meter scale.

3.8.2.2 Petiole length (cm)

The petiole length of the leaves was taken from the tagged plants in each replication after completion of harvesting period with the help of a meter scale.

3.8.2.3 Numbers of leaves per plant

Total number of leaves were counted from tagged plants in each replication after completion of harvesting period and expressed as average number of leaves per plant.

3.8.2.4 Plant spread (cm)

The spread of the tagged plants was recorded in east-west and north-south direction separately with the help of a meter scale and the average for each direction was calculated.

3.8.2.5 Plant (Fresh and dry) weight (g)

After completion of harvesting, tagged plants were uprooted and cleaned properly. They were then dried in oven at 70°C and the weight was recorded.

3.8.2.6 Runner production per plant

Total number of runners were counted from tagged plants in each replication after completion of harvesting period and expressed as average runner production per plant.

3.8.2.7 Chlorophyll content of leaves (mg/g)

After completion of harvesting, leaves from tagged plants were analysed for chlorophyll estimation. Chlorophyll content was measured as per method as suggested by Sadasivam and Manickam (1997). The details of procedure followed were as follows:

One gram of mature finely cut leaves was weighed and ground using 20 ml volume of acetone into a clean mortar. The sample was centrifuged (at 5000 rpm for 5 minutes) and the supernatant was transferred to a 100 ml volumetric flask. The process of centrifuging was repeated until the appearance of colourless residue. The mortar and paste were washed thoroughly with 80 percent acetone to get the clear extract of leaves. The volume was made upto 100 ml with 80 percent acetone. Then the absorbance of the solution was read at 645 and 663 nm against the blank solution of 80 percent acetone. The amount of chlorophyll present in the extract was calculated using the following equations :

$$\text{Chlorophyll (a) mg/g tissue} = 12.7(A_{663}) - 2.69(A_{645}) \times V/1000 \times W$$

$$\text{Chlorophyll (b) mg/g tissue} = 22.9(A_{645}) - 4.68(A_{663}) \times V/1000 \times W$$

$$\text{Total Chlorophyll mg/g tissue} = 20.2(A_{645}) + 8.02(A_{663}) \times V/1000 \times W$$

Where,

A = Absorbance at specific wave length

V = Final volume of chlorophyll extract in 80 per cent acetone

W = Fresh weight of tissue extracted

3.8.3 PRODUCTION PARAMETERS

3.8.3.1 Days taken to first flower initiation

It was recorded after planting when 5-6 plants in each replication started to flower. The average number of days from planting date was calculated to make the observation.

3.8.3.2 Days taken to 50 percent flowering

It was observed when 5-6 plants in each replication produced about 50 percent flower. The average number of days from planting date was calculated to record the observation.

3.8.3.3 Days taken to initiation of fruit set

The number of days taken to first fruit set was recorded when flower petals were observed dried off in the flower and achenes on fleshy receptacle started swelling. It was recorded when on 5-6 plants in each replication fruit set took place.

3.8.3.4 Days taken to 50 percent fruit set

It was recorded when 5-6 plants in each replication set 50 percent fruits. The average number of days from planting date was calculated to observe the reading.

3.8.3.5 Days taken to first harvest

It was observed when fruits were harvested first in each replication. The average number of days from planting date was calculated to record the observation.

3.8.3.6 Days taken to final harvest

Number of days taken to final harvest was counted from the date of first harvesting to the last harvesting in each treatment. The average was worked out and the data were recorded.

3.8.3.7 Number of pickings

The number of pickings was observed from the tagged plants in each replication by counting the number of time the fruits were harvested and average was drawn to record the data.

3.8.3.8 Fruit length (mm)

Fruit length of 10 fruits from each treatment was taken with the help of digital vernier caliper. The average length was then worked out to record the data.

3.8.3.9 Fruit width (mm)

The fruit width was recorded on same 10 fruits in which fruit length was recorded with the help of digital vernier caliper. The average width was recorded to have the data.

3.8.3.10 Length : diameter ratio

The length:diameter ratio of the same 10 fruits as used to record length and width was taken to observe the value of this character.

3.8.3.11 Fresh weight of fruit (g)

The weight of fruits from each tagged plants was taken on each date of harvest with the help of electronic top pan balance and the mean was expressed as weight of fruit in gram. Average weight of fruit was calculated after final harvest under each treatment.

3.8.3.12 Dry weight of fruit (g)

The dry weight of the fruit was recorded by drying the fruits in oven at 70°C till the constant weight upto 2 days. The value was averaged to record the data.

3.8.3.13 Number of fruits/plant

The number of fruits per plant was recorded on the same three tagged plants on which fruit set was studied. The number of fruits reaching harvestable maturity

was counted at each harvest and the value was expressed as number of fruits per plant.

3.8.3.14 Fruit yield per plant (g)

The yield per plant was recorded by adding yield of all the harvests obtained from selected plant. The value was averaged to record the data.

3.8.4 QUALITY PARAMETERS

3.8.4.1 Total Soluble Solids (°Brix)

Total soluble solids (TSS) were recorded with the help of hand refractometer. Fully ripe fruits of each treatment were taken and few (2-3) drops of juice from 5 fruits were taken separately and dropped over the prism of the refractometer. The value as observed was averaged to record the TSS (°Brix).

3.8.4.2 Titratable acidity (per cent)

The titratable acidity was determined by titrating the juice against standard alkali solution (0.1N NaOH). Pulp of sample weighing 2 gram was taken in distilled water. It was crushed and homogenized. The value of sample was made up to 100ml with distilled water. Aliquot of diluted sample measuring 10 ml was pipetted out and it was transferred in 250ml beaker. Phenolphthalein indicator @ 1-2 drops was added to the solution. The prepared sample was titrated against 0.1N NaOH alkali solution. The alkali was added drop by drop to the conical flask with constant stirring until the end point reached with disappearance of pink colour. The percentage of acidity was calculated from the following formula.

$$\text{Per cent of acidity} = \frac{\text{Titre volume} \times 0.1 \times 64 \times 10}{\text{Aliquot} \times 10}$$

3.8.4.3 TSS : Acid ratio

TSS/acid ratio was calculated by dividing the value of total soluble solids content by per cent acidity.

3.8.4.4 Sugars (per cent)

Reducing sugars and total sugars were estimated by Lane and Eynon (1984) copper titration method as explained below:

Reagents

1. Fehling's solution (A) : 69.28 g of copper sulphate was dissolved in water and the volume was made up to 1000ml and filtered through Whatman paper no. 4.
2. Fehling's solution (B): 346g of Rochelle salt and 100gNaOH was dissolved in water and volume was made up to 1000ml.
3. Methylene blue indicator: 1 g of methylene blue was dissolved in 100ml of water.
4. 45 percent neutral lead acetate solution: 250g of neutral lead acetate was dissolved in water and volume made was up to 500 ml.
5. 22 percent Potassium Oxalate solution: 110 g potassium oxalate was dissolved in water and volume was made up to 500ml.
6. Standard invert sugar solution: 100 ml of water and 5ml of concentrated HCl was added in 9.5g of AR Sucrose in 1litre volumetric flask. It was allowed to stand for 3 days at 20-25°C and then volume was made up to 1litre with water.25ml of the standard invert solution was pipetted out into a 100 ml volumetric flask and 50ml water was added. A few drops of phenolphthalein indicator was added and neutralized with 20 percent NaOH until the solution turned pink and was acidified with 1 N HCl adding it dropwise until one drop caused the pink colour to disappear. Then it was made up to mark with water (1ml=2.5mg of invert sugar).

Standardization of the Fehling's Solution

Each Fehling's solution (A and B) measuring 5 ml was taken into 250 ml conical flask and 25ml of water was added. Prepared standard invert sugar solution was taken in a 50 ml burette. 10 ml of standard invert sugar solution was added in the conical flask containing mixture of Fehling's solution. Then conical flask containing the mixture was heated and it was boiled for 2-3 minutes on low flame and invert sugar solution was added from the burette rapidly. Then, further quantity of sugar solution was added to the conical flask, which turned the solution colour of

conical flask into light blue. About 2 to 3 drops of methylene blue indicator was added and the titration was completed within 2-3 minutes by adding further quantity of invert sugar solution. At the end point a brick red precipitate developed.

Titre (Burette Reading) \times 2.5

$$\text{Factor for Fehling's solution} = \frac{\text{Titre (Burette Reading)} \times 2.5}{1000}$$

(g of invert sugar)

Total sugar (%)

Filtrate volume of 50ml was taken in 100ml conical flask and then hydrolyzed by adding 5ml. of conc. HCl. It was left for 24 hours. After that, 2 drops of phenolphthalein indicator was added and then it was neutralized by adding 40 percent NaOH solution. Pink colour appeared due to its neutralization. Then 1NHCL was added drop by drop until pink colour disappeared. Now, it was taken in burette. This solution was then titrated against Fehling's A and B as reducing sugar titration and the percentage of total sugar was worked out.

Factor \times Dilution \times 100 \times 100

$$\text{Total sugar (\%)} = \frac{\text{Factor} \times \text{Dilution} \times 100 \times 100}{50 \times \text{Titre value} \times \text{Wt. of Sample}}$$

50 \times Titre value \times Wt. of Sample

Non-reducing sugar (%) = (% Total invert sugar - % Reducing sugar originally present) \times 0.95

% Total Sugar = (% Reducing Sugar + % non-reducing sugar)

* (10ml of Fehling solution = 0.05 g of sugar)

Reducing Sugars (%)

Sample of pulp weighing 10g was taken and crushed and 100ml of distilled water was added in 250ml of conical flask. Lead acetate measuring 2ml was added to it. It was shaken and allowed to stand for 10 minutes and 2ml of potassium oxalate was also added. Then volume was made up to 250ml by adding distilled water. Then solution was filtered through Whatman paper No 4. and the filtrate was collected in a

conical flask. Each Fehling's solution (A and B) measuring 5ml was taken in a conical flask to which 50ml of distilled water was added. This was kept on electric heater for boiling. About 2-3 drops of methyl blue indicator were dropped into it. The Fehling's solution was also titrated by filtered fruit juice. The appearance of brick red colour determined the end point. Reducing sugar was calculated by the following formula:

$$\text{Reducing Sugar (\%)} = \frac{\text{mg of invert sugar} \times \text{Dilution} \times 100}{\text{Titre value} \times \text{Water volume of the sample} \times 100}$$

3.8.4.5 Juice (per cent)

The ripe fruits of strawberry were taken in muslin cloth and crushed. It was squeezed firmly to get juice. The juice was weighed with the help of balance and the percentage of juice was worked out on the basis of total weight of fruit taken for juice extraction.

3.8.4.6 Vitamin C (mg/100g fruit)

In Vit. C estimation, the following reagents were used:

1. Dye solution: 50mg of the sodium salt of 2,6-dichlorophenol-indophenol was dissolved in approximately 150ml of hot distilled water containing 42mg of sodium bicarbonate. The solution was allowed to cool and distilled water was added to make up the volume 200ml.
2. 3 per cent metaphosphoric acid: 30 g sticks of HPO_3 were dissolved in distilled water and the volume was made upto 1 liter.
3. Standard ascorbic acid: 100mg of 1-ascorbic acid was added to 3 per cent HPO_3 and volume was made upto 100ml. (1ml = 0.1mg of ascorbic acid). Then 10ml solution was taken from it and the volume was again adjusted to 100ml with 3 per cent MPA solution. Now 10ml standard ascorbic acid solution was taken and it was titrated with dye solution.

Procedure

Standardization of Dye

Ascorbic acid solution measuring 5ml was taken and 5ml of HPO₃ was added in a conical flask. A microburette was filled with the dye solution and then the dye solution was titrated till the end point reached with appearance of pink colour which persisted for 15 seconds. The dye factor was determined, i.e. mg of ascorbic acid per ml of dye, using following formula:

$$\text{Dye factor} = \frac{1}{\text{Titre value (burette)}}$$

Crushed sample weighing 2g was taken in a conical flask and the volume was adjusted upto 100ml with 3 per cent HPO₃ solution. This solution was kept for 10-15min. and then filtered. The filtrate solution measuring 10ml was titrated with standard dye 2, 6-dichlorophenol-indophenol to a pink end point appearance. It was titrated rapidly and preliminary determination of the titre was made. The ascorbic acid content of the sample was calculated by the following formula :

$$\text{Ascorbic acid (mg/100g pulp)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume make up} \times 100}{\text{Aliquot} \times \text{Vol. of solution taken for estimation}}$$

3.8.4.7 Anthocyanin (mg/100g pulp)

Aliquots weighing 5.0g of the homogenized strawberry samples were dissolved in 25 ml methanolic hydrochloric acid (85:15) solution. The samples were kept for 24 hours at cool temperature (4-5°C) for the extraction of anthocyanin pigment. The flocculate was filtered off by a Whatman paper 1 and the absorbance of the resulting clear liquid was measured at 535nm in Spectrophotometer (Model: Systronics 118). Anthocyanin content was calculated using the following formula:

$$\text{Anthocyanin (mg/100g pulp)} = \frac{\text{OD (abs 535\AA)} \times \text{volume of soln} \times 100}{\text{Weight of sample} \times 98.2} \times 100$$

3.8.4.8 Sensory score

A panel of five judges conducted organoleptic test of the fruits immediately after harvesting fruits of each treatment. The observation were recorded on the basis of flavour, colour, taste and general appearance of fruit and rated on 10.0 scale as under:

Excellent	:	9.1 to 10.0
Very Good	:	8.1 to 9.0
Good	:	6.1 to 8.0
Acceptable	:	5.1 to 6.0
Non-acceptable	:	0 to 5.0

3.8.5 ROOT GROWTH PARAMETERS

3.8.5.1 Fresh weight of root (g)

The fresh weight of the roots was taken by uprooting the plants. The roots of uprooted plants were washed properly. The roots were air dried to remove excess water. The weight was taken with the help of electric digital balance and average was taken out as the fresh weight of the roots.

3.8.5.2 Dry weight of root (g)

The dry weight of the roots was taken by drying the roots in oven at 70°C till the weight was constant upto 2 days. The value was averaged to get the dry weight of roots.

3.8.5.3 Root volume(cc)

The root volume was taken by water displacement method and average was worked out to record the value.

3.8.5.4 Root length(cm)

The root length of the plants was observed with the help of meter scale and average was worked out to record the root length.

3.8.5.5 No. of roots

Thin roots (<0.20mm)

The number of thin roots was observed by counting the number of roots with thickness less than 0.20 mm. The number was averaged to record the data.

Thick roots (> 0.20 mm)

The number of thick roots was observed by counting the roots of which thickness was greater than 0.20mm. The value was averaged to make the observation.

3.8.5.6 Root: shoot ratio

The root to shoot ratio was calculated by dividing the root weight by the shoot weight and average was worked out to record the value of ratio of root to shoot.

3.8.6 ANALYSIS OF SOIL SAMPLES

To assess the fertility status of soil, representative soil samples (0-30 cm depth) from three spots from each plot of experimental site was collected, composited and air dried. The samples were powdered using a wooden mortar and pestle and passed through 2 mm plastic sieve to avoid metallic contamination. The soil samples were analyzed for available pH, EC, organic carbon, nitrogen, phosphorus, potassium and water holding capacity before and after experiment as per the standard method.

3.8.6.1 pH

Soil:water suspension (1:2) was prepared by taking 20 gram of soil and 40 ml distilled water in 100 ml beaker. Soil pH was determined by using the suspension by glass electrode pH meter.

3.8.6.2 Electrical conductivity (dS m^{-1}) (Jackson, 1973)

Electrical conductivity of soil was determined in 1:2 soil water suspension by using Digital conductivity meter.

3.8.6.3. Organic carbon (per cent)

Soil organic carbon was determined by Walkley and Black's (1934) wet digestion method. Following reagents were used to determine organic carbon in soil:

- (a) **Standard 1 N, Potassium Dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) solution** : Exactly 49.04 gram of $\text{K}_2\text{Cr}_2\text{O}_7$ was dissolved in water and diluted to one litre.
- (b) **0.5 Ferrous ammonium sulphate solution** : Exactly 196.1g Fe $(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ was dissolved in 800 ml of distilled water containing 20 ml of concentrated H_2SO_4 and diluted to one litre.
- (c) **Diphenyl amine indicator**: Diphenyl amine weighing 0.5g was dissolved in 20 ml of water and 100 ml of concentrated H_2SO_4 .
- (d) **Orthophosphoric acid (85%)**
- (e) **Concentrated sulphuric acid.**

Calculation :

$$O.C.(%) = \frac{10(B - T)}{B} \times \frac{0.003 \times 100}{wt. of soil (g)}$$

Where,

B = Volume (ml) of ferrous ammonium sulphate solution required.

T = Volume of ferrous ammonium sulphate solution needed for titration of soil sample.

3.8.6.4. Available Nitrogen (kg/ha)

Available nitrogen was determined by using alkaline potassium permanganate method as suggested by Subbiah and Asija (1956).

Reagents

(a) **0.32 percent KMnO₄ solution** : 3.2 gram pure KMnO₄ was dissolved in distilled water and diluted to one litre.

(b) **2.5 percent NaOH Solution** : 25 gram NaOH was dissolved in distilled water and diluted to one litre.

(c) **0.02 N H₂SO₄**: 0.56 ml of concentrated H₂SO₄ was dissolved and the volume was made up to one litre and then standardized with 0.02 N NaOH using phenolphthalein indicator.

(d) **0.02 N NaOH** : 0.8 gram NaOH was dissolved in distilled water and diluted to one litre.

(e) **Methyl red indicator**: 0.07 gram methyl red was dissolved in 100 ml of 95% ethanol.

Calculation

$$\text{Available N (kg/ha)} = R \times 31.36$$

Where R = Volume of 0.02 N H₂SO₄ required for titration.

3.8.6.5 Available Phosphorus (kg/ha)

Available phosphorus was determined with extraction by 0.5 M NaHCO₃ solution adjusted at pH 8.5 as suggested by Olsen *et al.*, (1954).

Reagents

(a) **0.5 Sodium Bicarbonate**: Exactly 42 gram of NaHCO₃ was dissolved in distilled water and volume was made up to one litre. The pH of this solution was adjusted to 8.5 pH with 1 N NaOH.

(b) **Activated Charcoal (Phosphorous Free)**

(c) **Ammonium molybdate (1.5 percent):** 15 gram of ammonium molybdate was dissolved in 300 ml of warm distilled water (about 50°C). After mixing it was allowed to cool down. Then 342 ml of concentrated HCl was added gradually by stirring it. It was diluted to one litre using distilled water.

(d) **Stannous chloride (stock solution):** Exactly 10g of SnCl₂ was dissolved in 25 ml concentrated HCl, and a piece of tin was added followed by heating, till it became clear. The solution was stored in amber coloured bottle.

(e) **Working solution of stannous chloride:** 0.5 ml stock solution of SnCl₂ was taken, and volume was made up to 66 ml with distilled water.

(f) **Standard solution of phosphorus:** Exactly 0.43 gram of A.R. KH₂PO₄ (oven dried at 40°C) was taken and it was dissolved in about half a litre of distilled water. Then 25 ml of 7 N H₂SO₄ was added and volume was made up to 1 litre with distilled water. This gave 100 ppm P.

Standard Curve

2.5 ppm P solution was prepared by taking 2.5 ml of 100 ppm solution in 100 ml volumetric flask and its volume was made up using distilled water. The standard curve was prepared by taking different concentration of P, i.e. 1, 2, 3, 4, 5 and 10 ml of 2.5 ppm solution in 25 ml volumetric flask. It had 0.1, 0.2, 0.3, 0.4, 0.5 and 1.0 ppm P. These readings were taken on calorimeter.

$$\text{Available P (kg / ha)} = \frac{R \times \text{Volume of extract}}{\text{Vol. of aliquot}} \times \frac{2.24 \times 10^6}{\text{wt. (g) of soil} \times 10^6}$$

$$\text{Where R = ppm p in the aliquot} = \frac{R \times 100}{5} \times \frac{2.24}{5}$$

$$(\text{Obtained from standard curve}) = (\text{ppm P}) R \times 8.96 \times 2.29$$

3.8.6.6. Available Potassium (kg/ha)

Available potassium was determined by extracting the soil by shaking with N neutral ammonium acetate solution by flame photometer as suggested by Meston (1956).

(a) **N neutral ammonium acetate solution:** 700 ml of distilled water was taken in a one litre volumetric flask. Then, 57 ml glacial acetic acid (99.5 percent) along with 69 ml of

conc. ammonium hydroxide was added. It was then diluted to volume of 900 ml and pH was adjusted to 7.0 by the addition of 3N NH₄OH, and volume was made upto 1 lit.

(b) Standard solution: Exactly 1.908 gram of AR grade KCl was dissolved in distilled water and volume was made upto 1 lit. This solution contained 1 mg K/ml 1000 ppm K.

(c) Working solution of K: Taking 10 ml of 1000 ppm K solution in 100 ml volumetric flask and its volume was made up to 100ml. This gave 100 ppm K.

Standard Curve

From the 100 ppm solution, 10, 15, 20, 25, 30 and 40 ml of K weretaken in each 100 ml volumetric flask and volume was make up to 100 ml using distilled water. The curve was obtained by plotting the readings of flame photometer against the various concentrations of K.

Calculation:

$$\text{Available K (kg / ha)} = \frac{R \times \text{Vol. of Extract} \times 2.24 \times 10^6}{\text{Wt. of soil taken} \times 10^6}$$

Where,

R = ppm of K in the extract (obtained from the standard curve)

$$= \text{ppm K} \times 11.2$$

3.8.6.7 Water holding capacity (per cent)

A filter paper was fitted at the perforated bottom of a circular brass box and weighed. The box was filled with soil with continuous tapping. The box was submerged in water upto 10cm depth for 1 hour. Box was removed and wiped off to get dry and weighed immediately. The box was then put in oven at 105°C till constant weight was achieved. 10 filter paper was cut to the size of the box and weighed. Filter paper was saturated with water and weighed again. Average amount of water absorbed by the filter was then subtracted.

Calculation:

$$\text{Water holding capacity of the soil} = \frac{\text{Actual amount of water held by the soil}}{\text{Weight of oven dry soil}} \times 100$$

3.9 STATISTICAL ANALYSIS

The mean values of the characters were used for statistical analysis.

Analysis of variance for RBD

Analysis of variance for individual character was done on the basis of mean values as suggested by Panse and Sukhatme (1942). The model of analysis of variance adopted for it is given below.

Source of variation	d.f	Sum of Square (S.S.)	Mean Squares (M.S)	F-cal. Value	F-table value at 5 % level of significance
Treatment	(t-1)	TSS	TMS	F _T	F(t-1), (t-1)(r-1)
Replication	(r-1)	RSS	RMS	F _R	F(r-1),(t-1)(r-1)
Error	(t-1)(r-1)	ESS	EMS		

Standard error of difference between genotype mean was calculated as:

$$SE_d = \sqrt{\frac{2EMS}{r}}$$

Where,

- r = Number of replications
- t = Number of treatments
- TSS = Treatment sum of square
- RSS = Replication sum of square
- ESS = Error sum of square
- TSS = Total sum of square
- TMS = Treatment mean square
- RMS = Replication mean square
- EMS = Error mean square

Chapter - 4 EXPERIMENTAL FINDINGS

The results obtained in the present investigation are presented here in suitable heads/sub-heads.

4.1 Growth parameters

4.1.1. Crown height (cm)

The data recorded regarding the effect of different mulch materials and growing environments on crown height of strawberry are presented in Table 4.1.1 and depicted through Figure 4.1.1. The treatment M_1T_2 : Rice husk+Naturally ventilated polyhouse recorded the maximum crown height (29.33cm), whereas, the minimum crown height (14.89cm) was recorded in treatment (M_0T_1): No mulch+Agro shade net. Treatments M_3T_2 , and M_2T_2 were found at par from each other. All other treatments were found significantly different from each other.

4.1.2. Petiole length (cm)

Data recorded for the effect of different mulch materials and growing environments on petiole length of strawberry plants are presented in Table 4.1.1 and depicted through Figure 4.1.1. Significant differences among treatments for their effect on petiole length were found. Almost 160 per cent difference in petiole length was observed between the minimum and the maximum petiole length in various treatments in various environments. Strawberry plants grown in treatment M_1T_2 : Rice husk+Naturally ventilated polyhouse recorded the maximum petiole length (20.27cm). On the other hand, the minimum petiole length (7.80cm) was observed in plants grown in M_0T_1 : No mulch+Agro shade net. Treatments M_0T_2 , M_0T_3 , M_1T_3 , M_2T_0 , M_2T_3 , M_3T_0 and M_3T_3 were at par with respect to petiole length.

4.1.3. Number of leaves per plant

Irrespective of the mulch materials used, open field conditions recorded significantly higher number of leaves per plant in strawberry (Table 4.1.1 and Figure 4.1.1). The maximum number of leaves per plant (97.44) was recorded in treatment M_2T_0 : White polythene+Open field conditions. In contrast, lower number of leaves

(18.33) was recorded in the treatment M_0T_1 : No mulch+Agro shade net. Treatments M_0T_0 , M_0T_2 , M_1T_2 , M_1T_3 , M_3T_2 and M_3T_3 were noted at par with each other.

4.1.4. Plant spread (cm)

Data pertaining to plant spread (E-W and N-S) of strawberry plants grown with use of mulch in different environments. Table 4.1.2 and Figure 4.1.2 reveal that in both E-W and N-S directions, irrespective of mulch material, there was more spread in plants grown in naturally ventilated polyhouse condition. The maximum E-W spread (51.80cm) and N-S (49.88cm) spread was recorded in plants grown with the treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse, whereas, minimum E-W spread (26.05cm) was observed in treatment M_3T_1 : Black polythene mulch+Agro shade net and minimum N-S spread (24.94cm) was recorded in the treatment M_0T_1 : No mulch+Agro shade net. Treatments M_2T_2 , M_0T_2 , M_3T_0 and M_2T_0 were observed at par with each other in respect to E-W spread. However, as regard to N-S spread, treatments M_1T_2 , M_2T_2 , M_2T_0 and M_0T_2 were found at par.

4.1.5. Plant weight (fresh and dry) (g)

Observations recorded for plant weight (fresh and dry weight) of strawberry as a result of mulching and growing environments are presented in Table 4.1.3 and Figure 4.1.3. Strawberry plants in treatment M_1T_2 : Rice husk mulch+Naturally ventilated polyhouse recorded maximum fresh weight (235.00g) and dry weight (57.28g) in comparison to all other treatment combinations. Plants grown in treatment M_0T_1 : No mulch+Agro shade net had significantly minimum plant fresh weight (21.00g). The minimum plant dry weight (5.00g) was recorded in treatment M_0T_1 : No mulch+Agro shade net. There is significant difference among all the treatments.

4.1.6. Runner production per plant

Although, the runner production in strawberry starts after the completion of the crop harvest, however, in some treatments there had been production of runners during the experiment. Data relating to the effect of mulch materials and growing environments on runner production of strawberry are presented in Table 4.1.4 and depicted through Figure 4.1.4. The maximum number of runners per plant (4.00) was observed where plants were grown in treatment M_3T_3 : Black polythene+Fan pad system

greenhouse, while, the minimum number of runners per plant (0.11) was produced in the treatment M_0T_0 : No mulch+Open field. All the other treatments are non-significantly different from each other.

4.1.7. Chlorophyll content (mgg^{-1})

The data recorded for total chlorophyll in strawberry plants grown with different mulches and growing environments are presented in Table 4.1.4 and depicted in Figure 4.1.4. The total chlorophyll content was maximum (3.26 mgg^{-1}) in plants grown in treatment M_2T_0 : White polythene+Openfield, followed by 2.80 mgg^{-1} in plants those grown in M_3T_2 : Black polythene+Naturally ventilated polyhouse. The minimum total chlorophyll content (1.64 mgg^{-1}) was recorded in plants that were grown in treatment M_0T_3 : No mulch+Fan pad system greenhouse. Other treatments M_0T_2 , M_0T_3 , M_1T_1 , M_2T_1 and M_3T_3 showed no significant difference in respect to chlorophyll content.

4.2. Production parameters

4.2.1. Days taken to first flower initiation

The data recorded with respect to days taken to first flower initiation are presented in Table 4.2.1 and depicted in Figure 4.2.1. A perusal of the data reveals that there was considerable variation in the time taken to initiation of first flowering among the strawberry plants with different mulch materials and growing environments. The number of days taken to first flower initiation in plants ranged between 21 and 36 days. Treatment combination M_3T_3 : Black polythene+Fan pad system greenhouse resulted in the earliest initiation of flowering (21.66 days) while it took more number of days (35.89 days) in the combination M_1T_1 : Rice husk+Agroshade net. Statistical analysis showed that the treatment combinations had non-significant influence on the time taken to first initiation of flowering.

4.2.2. Days taken to 50 per cent flowering

Table 4.2.1 and Figure 4.2.1 depict the data as regard to days taken to 50 per cent flowering. Significant differences were found in the time taken to achieve 50 per cent flowering among different mulches in different growing environments. The time period taken for completion of 50 per cent flowering ranged between 82.77 to 112.22 days. The

minimum number of days (82.77 days) required to 50 per cent flowering was recorded in M₃T₃: Black polythene+Fan pad system greenhouse and the maximum number of days (112.22 days) was recorded in treatment M₀T₁: No mulch+Agroshade net. Treatments M₀T₀, M₀T₃, M₁T₃, M₂T₀, M₂T₃, M₃T₀, M₃T₁, M₃T₂ and M₃T₃ were found at par with each other.

4.2.3. Days taken to first fruit set

Table 4.2.1 and Figure 4.2.1 depict the trend as regard to the effect of mulch material and growing conditions on the days taken to first fruit set. Mulching material and growing conditions had significant effect on the days taken to first fruit set. Strawberry plants grown in treatment M₃T₃: Black polythene+Fan pad system greenhouse took the minimum time (26.44 days) for first fruit set, while the plants in treatment M₁T₁: Rice husk+Agroshade net took the maximum days (43.44 days) for first fruit set. Treatments M₀T₀, M₀T₁, M₀T₃, M₁T₂, M₁T₃, M₂T₀, M₂T₃, M₃T₀ and M₁T₂ were found at par with each other.

4.2.4. Days taken to 50 per cent fruit set

The data recorded with respect to the effect of mulching and growing environments on the time taken to 50 per cent fruit set in strawberry cv. Winter Dawn are presented in Table 4.2.1 and depicted through Figure 4.2.1. The time taken for attainment of 50 per cent fruit set ranged between 89 and 117.26 days. The minimum days (89.00 days) taken to 50 per cent fruit set was recorded in the treatment M₂T₂: White polythene+Naturally ventilated polyhouse and the maximum days (117.26 days) was recorded in M₀T₁: No mulch+Agro shade net. All other treatments were found non-significantly different from each other.

4.2.5. Days taken to first harvest

The time taken to first harvest ranged from 52 days to 72 days (Table 4.2.2 and Figure 4.2.2), indicating that mulching and growing conditions could influence the time of first harvest by almost 20 days. The minimum days (52.30 days) to first harvest was recorded in treatment M₁T₀: Rice husk+Open field while the plants grown in treatment M₁T₁: Rice husk+Agro shade net took the maximum days (71.89 days) for first harvest.

Significant difference was found among the different treatment combinations viz. M_0T_2 , M_0T_3 and M_2T_1 in their effect on days taken to first harvest. Treatments M_3T_2 , M_3T_3 , M_3T_0 , M_2T_3 , M_2T_0 and M_1T_3 were found at par.

4.2.6. Days taken to final harvest

Table 4.2.2 and Figure 4.2.2 depict the days taken to final harvest of fruits. A perusal of the data indicate that strawberry plants grown in treatment M_0T_1 : No mulch+Agro shade net had the minimum (88.33 days) productive period. The days taken to final harvest was maximum (139.44 days) in plants which were grown in treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse. Treatments M_0T_2 , M_0T_3 , M_1T_0 , M_1T_2 , M_1T_3 , M_2T_0 , M_2T_2 , M_2T_3 , M_3T_0 , M_3T_1 and M_3T_3 were noted at par to each other in which it took 115.33, 122.44, 113.33, 130.00, 134.44, 116.00, 122.00, 124.22, 120.78 and 136.66 days respectively.

4.2.7. Number of pickings

The data pertaining to the effect of mulch material and growing environments on number of pickings of strawberry has been presented in Table 4.2.2 and Figure 4.2.2. It can be apprehended from the data that maximum number of pickings (26.00) were recorded in plants grown in treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse condition. The minimum number of picking (2.66) was recorded in plants grown in treatment M_0T_1 : No mulch+Agro shade net. Treatments M_1T_0 , M_2T_0 and M_2T_2 didn't show any significant differences in number of picking.

4.2.8. Fruit length (mm)

There was significant difference among various treatment combinations with respect to their effect on fruit length of strawberry (Table 4.2.3 and Figure 4.2.3). Strawberry fruit length ranged from 27.50mm to 54.00mm. The fruit length in plants grown in treatment M_3T_0 : Black polythene+Open field was maximum (54.00mm) than those obtained in this study. However, the minimum (27.50mm) length of fruit was recorded in treatment M_2T_1 : White polythene+Agro shade net. Treatments M_0T_0 , M_1T_0 and M_2T_0 were found at par with each other.

4.2.9. Fruit width (mm)

Data pertaining to the effect of mulches and growing environments on fruit width of strawberry are presented in Table 4.2.3 and depicted through Figure 4.2.3. Fruits produced in the treatment M_3T_0 : Black polythene+Open field had the maximum fruit width (42.59mm). Fruits grown in the treatment M_2T_1 : White polythene+Agro shade net recorded the minimum fruit width (22.37mm). Treatment M_0T_0 , M_1T_0 , and M_2T_0 was found at par with each other in which fruit width varied from 37.60, 38.51 and 40.67mm respectively.

4.2.10. Length:diameter ratio

The data recorded with respect to the effect of mulches and different growing environments on length:diameter ratio are presented in Table 4.2.3 and Figure 4.2.3. Maximum length: diameter ratio (1.30) was recorded in treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse, M_0T_0 : No mulch+Open field and M_0T_1 : No mulch+Agro shade net while minimum (1.00) was recorded in treatment M_3T_3 : Black polythene+Fan pad system greenhouse. Treatments M_1T_1 and M_1T_2 were found at par with regard to length: diameter ratio.

4.2.11. Fruit weight (Fresh and dry)(g)

The fresh weight and dry weight of strawberry fruits grown with different mulching materials in different growing environments are given in Table 4.2.4 and Figures 4.2.4. Fruits in the treatment M_3T_0 : Black polythene+Open field recorded the maximum fresh weight (36.74g) and dry weight (2.88g) as compared to other treatments. Treatment M_2T_1 : White polythene+Agro shade net and M_1T_1 : Rice husk+Agro shade net recorded minimum fresh weight (7.10g) and dry weight (0.51g) among all the treatments respectively. M_2T_0 , M_1T_0 and M_0T_0 did not vary significantly with each other regarding fresh as well as dry fruit weight.

4.2.12. Number of fruits per plant

The data pertaining to the number of fruits per plant are presented in Table 4.2.5 and depicted through Figure 4.2.5. A wide difference was recorded in the number of fruits among various treatment combinations. The maximum number of fruits per plant (39.66) was recorded in plants grown in the treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse. The minimum number of fruits (4.66) was recorded in plants grown

intreatment M₀T₁: No mulch+Agro shade net. Treatments M₁T₂, M₁T₃, M₂T₀, M₃T₀ and M₃T₃ were observed non-significantly different from each other.

4.2.13. Fruit yield per plant (g)

Data recorded for fruit yield per strawberry plant as affected by mulches and different growing environments are presented in Table 4.2.5 and Figure4.2.5. It is clearly evident from the data that strawberry grown intreatment M₃T₀: Black polythene+Open field resulted in maximum fruit yield per plant (536.55g) while the minimum yield per plant (29.22g) was recorded from the treatment M₀T₁: No mulch+Agro shade net. Treatments M₀T₀, M₀T₂, M₁T₀, M₁T₂, M₁T₃, M₂T₀, M₂T₃ and M₃T₂ were found at par with each other.

4.3. Quality parameters

4.3.1. Total soluble solids (°Brix)

Table 4.3.1 and Figure 4.3.1 depict the total soluble solids of strawberry fruits grown with different mulches in different growing environments. The TSS of strawberry fruits ranged from 6 – 7.3°B. There was no significant difference among various treatment combinations for their effect on TSS. However, strawberry plants grown using treatment M₃T₀: Black polythene+Openfield had fruits with the maximum TSS (7.30°B) while the minimum (6.00°B) was recorded intreatment M₀T₁: No mulch+Agro shade net.

4.3.2. Titratable acidity (per cent)

No significant difference was recorded among various treatment combinations in their effect on titratable acidity of the fruits (Table 4.3.1 and Figure4.3.1). The titratable acidity of strawberry fruits ranged from 1.45 to 1.90 per cent with no difference between them. The maximum (1.90 per cent) mean titratable acidity was recorded in fruits grown intreatment M₃T₃: Black polythene+Fan pad system greenhouse, while, the minimum

(1.45 per cent) was found in fruits grown in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse.

4.3.3. TSS/acid ratio

Table 4.3.1 and Figure 4.3.1 depict the TSS/acid ratio of strawberry fruits grown with different mulches in different growing environments. Maximum TSS/acid ratio (4.97) was observed in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse. The minimum TSS/acid ratio (3.49) was recorded in treatment M₃T₃: Black polythene+Fanpad system greenhouse. Rest all treatments were found non-significantly different from each other.

4.3.4. Sugar(per cent)

4.3.4.1 Total sugars

Although no significant differences were found among various treatment combinations for their effect on TSS, there was variability among treatments for total sugars content (Table 4.3.2 and Figure 4.3.2). A perusal of the data reveals that maximum total sugar content (5.15 per cent) was recorded in fruits grown in treatment M₃T₀: Black polythene+Open field, whereas the minimum total sugars content (2.10 per cent) was found in fruits grown in the treatment M₀T₂: No mulch+Naturally ventilated polyhouse. Treatments M₀T₀, M₁T₀, M₁T₁, M₁T₂, M₁T₃, M₂T₂ and M₃T₃ were found at par with each other.

4.3.4.2 Reducing sugars

Table 4.3.2 and Figure 4.3.2 depicts the data regarding the reducing sugar recorded in the strawberry fruits. They reveal maximum reducing sugar (4.06 per cent) in fruits produced in treatment M₃T₀: Black polythene+Open field while minimum (1.51 per cent) in treatment combination M₀T₂: No mulch+Naturally ventilated polyhouse. M₀T₀, M₁T₀, M₁T₁, M₁T₂, M₁T₃, M₂T₂ and M₃T₃ differed non-significantly.

4.3.5 Juice (per cent)

The data recorded as regard to the effect of different mulch materials and growing environments on juice percentage of strawberry fruits are given in Table 4.3.3 and Figure 4.3.3. There was significant differences among the treatment combinations for their effect

on juice percentage of strawberry fruits which ranged between 65.11-96.10 per cent. The maximum juice percentage (96.10 per cent) was observed in fruits which were grown in the treatment M_3T_0 : Black polythene+Open field, while, the minimum juice percentage (65.11 per cent) was recorded in treatment M_1T_0 : Rice husk+Open field. Treatments M_2T_0 , M_3T_1 , M_0T_3 and M_3T_2 were observed at par with each other.

4.3.6 Vitamin C ($\text{mg}100\text{g}^{-1}$)

The data pertaining to the effect of mulch material and growing environments on vitamin C content of strawberry are presented in Table 4.3.3 and Figure 4.3.3. The vitamin C content of fruits ranged from $39.20 \text{ mg}100\text{g}^{-1}$ to $52.54 \text{ mg}100\text{g}^{-1}$. The maximum vitamin C ($52.54 \text{ mg}100\text{g}^{-1}$) was recorded in treatment M_3T_0 : Black polythene+Open field while minimum ($39.20 \text{ mg}100\text{g}^{-1}$) was recorded in treatment M_1T_0 : Rice husk+Open field. Vitamin C content among all the treatments were found non-significantly different from each other.

4.3.7 Anthocyanin content ($\text{mg}100\text{g}^{-1}$)

Data recorded with respect to the effect of different mulching materials and growing environments on total anthocyanin content of strawberry fruit are presented in Table 4.3.4 and depicted through Figure 4.3.4. The total anthocyanin content in strawberry fruit ranged between 28.75 – $45.51 \text{ mg}100 \text{ g}^{-1}$. The maximum total anthocyanin content ($45.51 \text{ mg} 100 \text{ g}^{-1}$) was recorded in plants grown in treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse and the minimum total anthocyanin content ($28.75 \text{ mg} 100 \text{ g}^{-1}$) was recorded in treatment M_0T_3 : No mulch+Fan pad system greenhouse. Treatments M_2T_3 , M_1T_1 , M_0T_2 and M_3T_0 were at par for anthocyanin content of fruit.

4.3.8 Sensory score

The sensory score of strawberry fruits as influenced by different mulches and growing environments is depicted in Table 4.3.4 and Figure 4.3.4. Fruits scoring maximum sensory score (8.35) were those grown in the treatment M_3T_0 : Black polythene+Open field, while, minimum score (6.27) was recorded in fruits produced in the

treatment M_0T_3 : No mulch+Fan pad system greenhouse. Treatments M_2T_0 and M_1T_0 were at par for sensory score of fruits. All other treatments were found significantly different from each other.

4.4 Root growth parameters

4.4.1 Root weight (fresh and dry) (g)

Data recorded with respect to the effect of mulch materials and growing environments on root weight are presented in Table 4.4.1 and depicted through Figure 4.4.1. As appeared from the data, there was significant differences among various treatment combinations in their effect on root weight of strawberry. The maximum freshweight (37.76 g) and dry weight (7.32g) of root was recorded in strawberry plants grown in treatment M_3T_0 : Black polythene+Open field, while the minimum fresh weight (1.68g) and dry weight (0.80g) weight of root was observed in the treatment M_2T_1 : White polythene+Agro shade net. M_0T_3 , M_2T_2 , M_2T_3 and M_3T_1 were at par to each other as regard to root fresh and dry weight.

4.4.2 Root volume (cc)

Observations recorded for root volume of strawberry as influenced by the kind of mulch materials and growing conditions are presented in Table 4.4.2 and depicted through Figure 4.4.2. The root volumes differed significantly among various treatment combinations and ranged from 6.14 cubic centimetre to 45.55 cubic centimeter. The maximum (45.55 cubic centimetre) and minimum (6.14 cubic centimetre) root volume was observed in treatment M_3T_0 : Black polythene+Open field and M_0T_3 : No mulch+Fan pad system greenhouse, respectively. However, treatments M_1T_1 , M_1T_3 , M_2T_2 and M_2T_3 were noted at par.

4.4.3 Root length (cm)

Table 4.4.2 and Figure 4.4.2 indicate the observations recorded with respect to root length of strawberry grown with different mulch materials in different growing environments. A perusal of the data indicates that there was wide variation in the length of roots of strawberry in response to mulching materials used and the environmental conditions in which the plants were grown. The minimum root length (11.33 cm) was seen in the treatment M_0T_1 : No mulch+Agro shade net while the maximum root length

(28.22 cm) was recorded in plants grown in M_3T_0 : Black polythene+Openfield. This indicates an almost 150 per cent increase in the root length of strawberry plant grown in treatment M_3T_0 over that of treatment M_0T_1 . Treatments M_0T_0 , M_0T_2 , M_1T_0 , M_1T_2 , M_1T_3 , M_2T_2 , M_2T_3 , M_3T_1 and M_3T_3 were observed non-significantly different from each other.

4.4.4 Number of roots (Thin and Thick)

As regard to number of thin as well as thick roots (Table 4.4.3 and Figure 4.4.3), statistically significant differences were found among various treatment combinations. The maximum number of roots (190.55 and 176.11, respectively, for thin and thick roots) was recorded in the treatment M_3T_0 : Black polythene+Openfield, the minimum (26.11 and 31.66, respectively, for thin and thick roots) were recorded in treatment M_3T_1 : Black polythene+Agro shade net mulch. All other treatments were found significantly different from each other.

4.4.5 Root:Shoot ratio

The data recorded with respect to root: shoot ratio (Table 4.4.4 and Figure 4.4.4) highlight significant differences among various treatment combinations involving mulch materials and growing environments and the maximum root:shoot ratio (0.46) was observed in plants grown in treatment M_1T_0 : Rice husk+Open field, while the minimum (0.11) was recorded in treatment M_2T_3 : White polythene+Fan pad system greenhouse.

4.5 Soil parameters (after experiment)

4.5.1 pH

Data recorded regarding the effect of different mulch materials and growing environments on soil pH are presented in Table 4.5.1 and depicted through Figure 4.5.1. The maximum recorded value of pH (7.49) was observed in treatment M_3T_0 : Black polythene+Open field and the minimum recorded value of pH (6.46) in the treatment M_2T_2 : White polythene+Naturally ventilated polyhouse. All other treatments were non-significantly different from each other.

4.5.2 Electrical conductivity (dSm^{-1})

Table 4.5.1 and Figure 4.5.1 depict the electrical conductivity of the soil. From the perusal data it is apprehended that there is variation among the different treatment combinations. The maximum EC (0.91 dSm^{-1}) was recorded in the treatment M_0T_2 : No mulch+Naturally ventilated polyhouse. The minimum EC (0.35 dSm^{-1}) was found in treatment M_3T_0 : Black polythene+Open field. Treatments M_2T_0 , M_2T_1 , M_2T_2 , M_2T_3 , M_3T_1 and M_3T_3 were at par.

4.5.3 Organic carbon (per cent)

Data with reference to organic carbon percentage are presented in Table 4.5.1 and depicted through Figure 4.5.1. From the perusal of the data it is explicit that there had been variation in organic carbon content in various treatments. Maximum organic carbon (0.76 per cent) was observed in treatment M_1T_1 : Rice husk+Agro shade net and the minimum (0.43 per cent) in treatment combination of White polythene+Naturally ventilated polyhouse (M_2T_2 and M_2T_3 : White polythene+Fan pad system greenhouse). However, treatments M_0T_0 , M_0T_1 , M_0T_2 , M_1T_3 , M_2T_0 and M_3T_0 were noted at par.

4.5.4 Available Nitrogen (kg ha^{-1})

Observations recorded for available nitrogen are presented in Table 4.5.2 and depicted through Figure 4.5.2. Maximum available nitrogen (734 kg ha^{-1}) was recorded in the treatment M_1T_1 : Rice husk+Agro shade net while the minimum (415 kg ha^{-1}) was found in treatment M_2T_2 : White polythene+Naturally ventilated polyhouse and M_2T_3 : White polythene+Fan pad system greenhouse. Treatments M_0T_0 , M_0T_1 , M_0T_2 , M_1T_0 , M_1T_3 , M_2T_0 , M_3T_2 and M_3T_3 were at par as regard to available nitrogen.

4.5.5 Available Phosphorous (kg ha^{-1})

The data recorded for available phosphorous in different mulches and growing environments are presented in Table 4.5.2 and depicted through Figure 4.5.2. Maximum available phosphorous (58.13 kg ha^{-1}) was recorded in the treatment M_1T_2 : Rice husk+Naturally ventilated polyhouse and the minimum (25.01 kg ha^{-1}) in treatment M_0T_3 :

No mulch+Fan pad system greenhouse. M_0T_0 , M_0T_2 , M_1T_0 , M_1T_1 , M_1T_3 , M_2T_2 , M_3T_1 , M_3T_2 and M_3T_3 had non-significant difference among each other.

4.5.6 Available Potassium (kg ha^{-1})

Table 4.5.2 and Figure 4.5.2 depicts the data as regard to available potassium in the soil and reveals variations among the treatments. The available potassium ranged from 402.00-513.00 kg ha^{-1} . The maximum available potassium (513 kg ha^{-1}) was recorded in the treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse while the minimum available potassium (402 kg ha^{-1}) was recorded in from treatment M_3T_1 : Black polythene+Agro shade net. Treatments M_3T_3 , M_2T_2 , M_1T_3 , M_1T_1 , M_0T_2 , M_0T_1 and M_0T_0 were at par.

4.5.7 Water holding capacity (per cent)

Data pertaining to the effect of mulches in different growing environments on water holding capacity of soil are presented in Table 4.5.2 and depicted in Figure 4.5.2. Water holding capacity of the soil among the treatments was found different from each other and it was in the range of 23.12-53.90 per cent. Maximum water holding capacity (53.90 per cent) was recorded in the treatment M_1T_1 : Rice husk+Agro shade net while the minimum water holding capacity (23.12 per cent) was there in treatment M_2T_2 : White polythene+Naturally ventilated polyhouse. Treatments M_0T_2 , M_1T_0 , M_1T_2 , M_2T_1 , M_3T_0 and M_3T_1 were found at par with each other.

The experiment entitled **Effect of mulches on growth, production and quality of Strawberry (*Fragaria x ananassa*Duch.) cv. Winter Dawn in different growing environments** was conducted during 2013-14 at the Protected Cultivation Unit, College of Horticulture and Forestry, Jhalawar. The results obtained in the pursuit of underlaid objectives of the experiments are discussed here in various heads:

5.1 Plant Growth parameters

Data presented in Tables 4.1.1-4.1.4 and depicted in Figures 4.1.1-4.1.4 revealed that the plant growth parameters like crown height (cm), petiole length (cm), number of leaves per plant, plant E-W spread and N-S spread (cm), plant fresh weight and dry weight (g), runner production per plant and total chlorophyll content of leaves were significantly influenced by different mulches and growing environments.

The treatment M₁T₂: Rice husk+Naturally ventilated polyhouse recorded the maximum crown height (29.33cm), whereas, the minimum crown height (14.89cm) was recorded in treatment (M₀T₁): No mulch+Agro shade net. The maximum plant E-W spread (51.80cm) and N-S spread (49.88cm) was recorded in plants grown in the treatment M₃T₂: Black polythene+Naturally ventilated polyhouse, whereas, minimum E-W spread (26.05cm) was observed in treatment M₃T₁: Black polythene mulch+Agro shade net and minimum N-S spread (24.94cm) was recorded in the treatment M₀T₁: No mulch+Agro shade net. The present findings are in accordance with those as reported by Pires *et al.* (2006).

These findings may be attributed to favourable environment and better moisture conservation vis-a-vis suppression of weeds in better treatment which might have resulted in better plant growth parameters than other treatments (Qureshi *et al.*, 2012). Further, better plant growth in the treatment M₁T₂ may be due to favourable modification of hydrothermal regime and physico-chemical properties of soil (Dwivedi *et al.* (2000) and Hira *et al.* (2003). Similarly, Fear and Nonnecke, (1989);

Gupta and Acharya, (1994) and Mohamed, (2002), also recorded higher growth of strawberry in black plastic mulch.

Strawberry plants grown in treatment M₁T₂: Rice husk+Naturally ventilated polyhouse recorded the maximum petiole length (20.27cm). On the other hand, the minimum petiole length (7.80cm) was observed in plants grown in M₀T₁: No mulch+Agro shade net. The maximum number of leaves (97.44) was recorded in treatment M₂T₀: White polythene+Open field conditions. In contrast, minimum number of leaves (18.33) was recorded in the treatment M₀T₁: No mulch+Agro shade net. Maximum number of leaves in the treatment M₂T₀ might be related to better exploration of nutrients and water (Sturm *et al.* (2003).

Strawberry plants in treatment M₁T₂: Rice husk mulch+Naturally ventilated polyhouse recorded maximum fresh weight (235.00g) and dry weight (57.28g) in comparison to all other treatment combinations. Plants grown in treatment M₀T₁: No mulch+Agro shade net had significantly minimum fresh weight (21.00g). The minimum plant dry weight (5.00g) was recorded in treatment M₀T₁: No mulch+Agro shade net. The maximum number of runners per plant (4.00) was observed where plants were grown in treatment M₃T₃: Black polythene+Fan pad system greenhouse while the minimum number of runners per plants (0.11) was produced in the treatment M₀T₀: No mulch+Open field. Similar results as regard to black mulch has been supported by the findings as reported by Singh and Dwivedi, (2011) and Pop *et al.* (2013).

Maximum fresh and dry weight of the plant in treatment M₁T₂ may be explained in the light of better growth of the plant under its influence. However, maximum runner production in the treatment M₃T₃ may be understood behind the fact of more diversion of plant energy towards the vegetative growth (runner production) in comparison to reproductive growth as evidenced by the findings of lesser yield irrespective of treatments under fan pad system greenhouse.

The total chlorophyll content was maximum (3.26 mgg⁻¹) in plants grown in treatment M₂T₀: White polythene+Open field, followed by 2.80 mgg⁻¹ in plants which

were grown in M₃T₂: Black polythene+Naturally ventilated polyhouse. The minimum total chlorophyll content (1.64 mgg⁻¹) was recorded in plants which were grown in treatment M₀T₃: No mulch+Fan pad system greenhouse. Similar result has been observed by Sheng *et al.* (2011) in pear.

The increased chlorophyll content may be attributed to differential of synthesis and degradation of chlorophyll in treatment M₂T₀. More photo-oxidation of the chlorophyll pigment in M₀T₃ may be ascribed to minimum chlorophyll content in this treatment. The oxidative degradation of chlorophyll has been highlighted by Richmond and Lang, (1957); Fletcher,(1977) and Thiamann,(1980). Further, the high activity of enzyme chlorophyllase may also be attributed to less chlorophyll content in the leaves. The role of chlorophyllase in degrading chlorophyll has been highlighted by Kuroki *et al.*(1981) and Puroid and Barmere,(1981).

Increased vegetative growth in black polythene has been highlighted by Garget *al.* (2007) and Taparauskiene and Miseckaite, (2014) in strawberry.

5.2 Production parameters

Table 4.2.1 and Figure 4.2.1 represent the days taken to first flower initiation, days taken to 50 per cent flowering, days taken to initiation of fruit set and days taken to 50 per cent fruit set. All these parameters were significantly different from each other. Treatment combination M₃T₃: Black polythene+Fan pad system greenhouse resulted in the earliest initiation of flowering (21.66 days), while, it took more number of days (35.89 days) in the combination M₁T₁: Rice husk+Agro shade net. The minimum number of days (82.77 days) required to 50 per cent flowering was recorded in M₃T₃: Black polythene+Fan pad system greenhouse and the maximum number of days (112.22 days) was recorded in treatment M₀T₁: No mulch+Agro shade net. Strawberry plants grown in treatment M₃T₃: Black polythene+Fan pad system greenhouse took the minimum time (26.44 days) for first fruit set, while the plants in treatment M₁T₁: Rice husk+Agro shade net took the maximum days (43.44 days) for first fruit set. The minimum days (89.00 days) taken to 50 per cent fruit set was

recorded in the treatment M₂T₂: White polythene+Naturally ventilated polyhouse and the maximum days (117.26 days) was recorded in M₀T₁: No mulch+Agro shade net.

Such type of finding with treatment M₃T₃ may be attributed to favourable ambient conditions as prevailed in fan pad system greenhouse. In this environment, ambient temperature prevailed in the range of 20-30°C. Verheulet *al.*(2006) reported ambient temperature in the range of 20-26°C as critical to influence behaviour of strawberry cultivars.

Days taken to first harvest, days taken to final harvest and number of pickings are presented in the Table 4.2.2 and depicted through Figure 4.2.2. The minimum days (52.30 days) to first harvest was recorded in treatment M₁T₀: Rice husk+Open field while the plants grown in treatment M₁T₁: Rice husk+Agro shade net took the maximum days (71.89 days) for first harvest. Strawberry plants grown in treatment M₀T₁: No mulch+Agro shade net had the minimum (88.33 days) productive period. The days taken to final harvest was maximum (139.44 days) in plants that were grown in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse. Maximum number of picking (26.00) was recorded in plants grown in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse condition. The minimum number of picking (2.66) was recorded in plants grown in treatment M₀T₁: No mulch+Agro shade net.

Minimum days taken to first harvest as observed in the treatment M₁T₀ may be associated to increase in soil temperature and the prevention of flower buds from frost damage. Dwivediet *al.* (2004) has also elucidated the influence of prevailing climatic conditions in flowering duration in strawberry. Similar reason holds true for maximum number of pickings in strawberry plants. Further prevention of plants from the danger of frost may also be linked to the maximum number of days available for final harvest and maximum number of pickings as explained by Dinkel, (1978) and Kopylov, (1991). Das *et al.*(2012a) opined that longer bloom duration in greenhouse provides for maximum days to final harvest and the number of picking.

Data pertaining to fruit length (mm), fruit width (mm), length:diameter ratio, fresh fruit weight (g) and dry weight of fruit (g) are represented in Table 4.2.3 and 4.2.4 and depicted through Figure 4.2.3 and 4.2.4. The fruit length in plants grown in treatment M₃T₀: Black polythene+Open field was maximum (54.00mm) than any

other obtained in this study while the minimum (27.50mm) was recorded in treatment M₂T₁: White polythene+Agro shade net. The maximum fruit width (42.59mm) was observed in the treatment M₃T₀: Black polythene+Open field. The minimum fruit width (22.37mm) was recorded in the treatment M₂T₁: White polythene+Agro shade net. Length:diameter ratio was recorded maximum (1.30) in the treatment M₃T₂: Black polythene+Naturally ventilated polyhouse, M₀T₀: No mulch+Open field and M₀T₁: No mulch+Agro shade net while minimum (1.00) was recorded in treatment M₃T₃: Black polythene+Fan pad system greenhouse.

Such finding in treatment M₃T₀ may be due to more favourable modification of soil temperature. In this treatment, the temperature was recorded in the range of 21-24°C which was in the range of 16-21°C in all other treatments in open field over the entire maximum productive days i.e., 18th December, 2013 to 20th March, 2014 (Table 3.3 and Figure 3.3). Galletta *et al.* (1981) narrated the role of soil temperature on the fruit size of strawberry.

Maximum average fresh fruit weight (36.74g) was observed in the treatment M₃T₀: Black polythene+Open field and the minimum fresh weight (7.10g) was recorded in the treatment M₂T₁: White polythene+Agro shade net. Dry weight of fruit was found maximum (2.88g) in the treatment M₃T₀: Black polythene+Open field while minimum value (0.51g) of the same was recorded in M₁T₁: Rice husk+Agro shade net. Similar observations regarding larger fruits by mulching with black polythene have been reported by Mathad and Jholgiker (2005) and Kumar *et al.* (2012b).

The higher fresh weight might be attributed to vigorous growth of plants in black polythene mulches. Increase in dry weight might be due to the balancing of respiration by photosynthesis as explained by Salisbury and Ross (1986).

Table 4.2.5 and Figure 4.2.5 depict the number of fruits per plant and fruit yield per plant. The maximum number of fruits per plant (39.66) was recorded in plants grown in the treatment M₃T₂: Black polythene+Naturally ventilated polyhouse. The minimum number of fruits (4.66) was recorded in plants grown in treatment M₀T₁: No mulch+Agro shade net. Similar findings has also been reported by Nagalakshmi *et al.* (2002).

It may be attributed to more number of flowers produced by vigorous plants in this treatment.

Maximum fruit yield per plant (579.89g) was recorded in treatment M₃T₀: Black polythene+Open field and the minimum fruit yield per plant (29.22g) was recorded in M₀T₁: No mulch+Agro shade net. Similar observation has been reported by Singh and Ahmed, (2008) and Kheret *al.* (2010).

Higher yield per plant may be accounted to better plant growth owing to favourable hydrothermal regime of soil and complete weed free environment as provided in black polythene mulch. Sharma and Khokhar, (2006) explained that black polythene mulch increases the availability of nutrients and keeps the plots free from weeds thus resulting into higher crop load. Due to rise in soil temperature and better plant growth in M₃T₀ may also be linked to maximum fruit yield in this treatment. Favourable and integrated effect of moderation in hydrothermal regime that possibly enhanced the root growth for better uptake of water and nutrients might led to better yield Munguia *et al.* (1998).

5.3 Quality parameters

Data pertaining to various quality parameters viz. TSS (°B), titratable acidity (per cent), TSS/Acid ratio, total and reducing sugars (per cent), juice content (per cent), vitamic C (mg100g⁻¹), anthocyanin content (mg100g⁻¹) and sensory score are presented in Tables 4.3.1-4.3.4 and depicted in the Figures 4.3.1-4.3.4. The results obtained in various treatments differ from each other. The maximum TSS (7.30°B) was observed in M₃T₀: Black polythene+Open field. The minimum TSS (6.00°B) was recorded in M₀T₁: No mulch+Agro shade net.

Hancock (1999) mentioned that soluble solids are dependent on environmental conditions. The cause of increase in TSS in this treatment may be viewed in the fact that this environment increases the soil temperature and offers favourable conditions for nutrients, metabolite mobilization and energy and this ultimately favours increase in TSS.

The maximum titratable acidity (1.90 per cent) was observed in M₃T₃: Black polythene+Fan pad system greenhouse, while, minimum (1.45 per cent)

was recorded in M₃T₂: Black polythene+Naturally ventilated polyhouse. Maximum TSS/acid ratio (4.97) was observed in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse. The minimum TSS/acid ratio (3.49) was recorded in M₃T₃: Black polythene+Fan pad system greenhouse. However, TSS, titratable acidity and TSS/acid ratio are non-significantly different from each other. These results are in conformity with the findings those of Mathad and Jholgiker, (2005) and Singh *et al.* (2007). Hassan *et al.* (2000) recorded maximum TSS, minimum acidity and maximum TSS/acid ratio in strawberry.

These findings may be explained in relation to higher moisture conservation and maximum nutrient uptake in the treatment M₃T₂: Black polythene+Naturally ventilated polyhouse. Fruit harvested from plants mulched with black polythene had higher TSS and lower acidity than those harvested from plants mulched either with white polythene mulch or paddy straw mulch as highlighted by Gupta and Acharya, (1993); Hassan *et al.*(2000) and Sharma *et al.*(2004).

The maximum total (5.15 per cent) and reducing (4.01 per cent) sugar was recorded in fruits grown in treatment M₃T₀: Black polythene+Open field, whereas, the minimum total sugars content (2.10 per cent) was found in fruits grown in the treatment M₀T₂: No mulch+Naturally ventilated polyhouse. The minimum reducing sugar (1.51 per cent) was recorded in treatment combination M₀T₂: No mulch+Naturally ventilated polyhouse.

This type of finding may be due to favourable activity of enzyme saccharose phosphate synthase in the treatment M₃T₀: Black polythene+Open field. Hubbard *et al.* (1991) has cited the role of sugar accumulation dependent to the enzyme saccharose phosphate synthase. Better sugar content in the treatment M₃T₀ may be due to the better influence of M₃T₀ over the enzyme such as: invertase, pyrophosphate dependent phosphofructokinase (PEP) and fructose-1,6-biphosphatase (FBPase) (Bassonet *et al.*(2010).

Maximum vitamin C (52.54mg100g⁻¹) was recorded in M₃T₀: Black polythene+Open field while the minimum value (39.20mg100g⁻¹) was recorded

in M_1T_0 : Rice husk+Open field. Ascorbic acid (vitamin C) content of fruits is altered by environmental factors, time of harvesting, plant vigour and age of plant etc.

High ascorbic acid in M_3T_0 may be due to alteration in micro environment and better utilization of nutrients which causes favourable effect on plant growth and development (Reiss *et al.*(2004). Further, more light exposure and greater accumulation of photosynthates might have contributed to an increase in vitamin C content in berry (Sonkaret *al.*(2012) in the treatment M_3T_0 .

Maximum juice content(96.10 per cent) was observed in the treatment M_3T_0 : Blackpolythene+Open field while minimum (65.11 per cent) was recorded in M_1T_0 : Rice husk+Open field. The maximum anthocyanin content ($45.51\text{mg}100\text{g}^{-1}$) was observed in M_3T_2 : Black polythene+Naturally ventilated polyhouse while its minimum value ($28.75\text{mg}100\text{g}^{-1}$) was recorded in M_0T_3 : No mulch+Fan pad system greenhouse.

Anthocyanin accumulation in the ripening fruits depends on phenylalanine ammonia lyase (PAL) and UDPGFT (Uridine diphosphate glucose: flavonoid 3-o transferase) regulatory enzyme activities(Given *et al.*(1988); Cheng and Breen,(1991). More anthocyanin content in M_3T_2 may be due to better influence of it on the activities of regulatory enzymes.

On the basis of sensory score, fruits intreatment M_3T_0 : Black polythene+Open fieldwasrated at the highest (8.35) while the score was lowest (6.27) in case of fruits produced in M_0T_3 : No mulch+Fan pad system greenhouse. Such differential in sensory score may be due to differences in physico-chemical properties of strawberry under various degree of light reflectance by the mulches as quoted by Decoteau*et al.* (1988).They affirmed that plants grown on different types of plastic mulches respond to the small changes in ambient light induced by mulch colour.

Kasperbauer*et al.* (2001) reported that black polythene reflects less than 5 percent of incident radiation irrespective to growing environments. Thus, it may be assumed that the response of black mulch in terms of improvement of fruit qualities (TSS, titratable acidity, TSS/acid ratio, vitamin C, total sugar, reducing sugar and anthocyanin content) as found in the present experiment may be due to changes in substrate temperature more than to reflected light.

5.4 Root growth parameters

Data related to root growth parameters are presented in Tables 4.4.1-4.4.4 and depicted in Figures 4.4.1-4.4.4. Data revealed that root growth on different mulches and in different growing environments was significantly different from each other. The maximum fresh (37.76g) and dry (7.32g) weight of roots was observed in M₃T₀: Black polythene+Open field. The minimum fresh weight of roots (1.68g) was recorded in M₂T₁: White polythene+Agro shade net. The minimum dry weight (0.80g) was recorded in M₂T₁: White polythene+Agro shade net. The maximum root volume (45.55cc) was observed in M₃T₀: Black polythene+Open field. The minimum volume of roots (6.14cc) was observed in M₀T₃: No mulch+Fan pad system greenhouse. Similar results have been observed by Verma *et al.* (2005).

The maximum root length (28.22 cm) was recorded in plants grown in M₃T₀: Black polythene+Open field. The minimum root length (11.33 cm) was seen in the treatment M₀T₁: No mulch+Agro shade net while the. The maximum number of thin (190.55) and thick (176.11) roots was recorded in the treatment M₃T₀: Black polythene+Open field. The minimum number of thin roots (26.11) was observed in treatment M₃T₁: Black polythene+Agro shade net mulch. The minimum number of thick roots (31.66) was observed in treatment M₃T₁: Black polythene+Agro shade net mulch. The maximum root: shoot ratio (0.46) was observed in plants grown in treatment M₁T₀: Rice husk+Open field, while, the minimum (0.11) was recorded in treatment M₂T₃: White polythene+Fan pad system greenhouse. Similar results have been observed by Kumar and Dey, (2012) in strawberry.

Sandal *et al.* (2007) observed mulches as effective in increasing root growth owing to improved hydrothermal regimes. Black polythene mulch resulted in overall better root growth parameters. The more favourable effect of black polythene mulch in modifying the soil environment might be the reason for improved root length, root weight and root volume (Verma *et al.* (2005).

5.5 Soil parameters (after experiment)

Table 4.5.1 and 4.5.2 and Figure 4.5.1 and 4.5.2 depict the soil nutrient status after experiment. The maximum (7.49) recorded value of pH (near neutral) was recorded

in treatment M₃T₀: Black polythene+Open field and the minimum recorded value of pH (6.46) in the treatment M₂T₂: White polythene+Naturally ventilated polyhouse.

It may be due to the fact that with mulching there is rise in temperature, more intensive mineralization and generation of large amount of organic acid and CO₂ which might lead in the formation of carbonic acid which in turn perhaps resulted in lowering the soil pH (Cabilovoskiet al.(2014).

The maximum EC (0.91 dSm⁻¹) was recorded in the treatment M₀T₂: No mulch+Naturally ventilated polyhouse. The minimum EC (0.35dSm⁻¹) was recorded in M₃T₀: Black polythene+Open field treatment.

The reduced EC in the treatment might be due to its influence on the generation of organic acid and CO₂(Cabilovoskiet al. (2014).

Maximum organic carbon (0.76 per cent) was observed in treatment M₁T₁: Rice husk+Agro shade net and the minimum (0.43 per cent) in both treatments i.e. White polythene+Naturally ventilated polyhouse (M₂T₂) and M₂T₃: White polythene+Fan pad system greenhouse. Maximum available N (734 kg ha⁻¹) was recorded in the treatment M₁T₁: Rice husk+Agro shade net while the minimum (415 kg ha⁻¹) was found in treatment M₂T₂: White polythene+Naturally ventilated polyhouse and M₂T₃: White polythene+Fan pad system greenhouse.

Such observations may be due to better decomposability of rice husk mulch. An increase in the total content of soil organic carbon in organic mulch has been established by Marinari et al.(2010). Natural organic mulch eventually break down and becomes part of the soil and a source of plant nutrients (Sharma et al.(1998); Bond and Grundy, (2001); Gruber et al.(2008).

Maximum available P (58.13 kg ha⁻¹) was recorded in the treatment M₁T₂: Rice husk+Naturally ventilated polyhouse and the minimum (25.01 kg ha⁻¹) in treatment M₀T₃: No mulch+Fan pad system greenhouse. The maximum available K (513 kg ha⁻¹) was recorded in the treatment M₃T₂: Black polythene+Naturally

ventilated polyhouse while the minimum available potassium (402 kg ha^{-1}) was recorded in treatment M_3T_1 : Black polythene+Agro shade net.

These findings may be attributed to better conservation of nutrients in better treatments. The role of mulches in conservation of nutrients has been narrated by Gruber *et al.*(2008).

Maximum water holding capacity (53.90 per cent) was recorded in the treatment M_1T_1 : Rice husk+Agro shade net, while, the minimum (23.12 per cent) in the treatment M_2T_2 : White polythene+Naturally ventilated polyhouse.

This may be attributed to better increase in organic matter in the soil which perhaps increased water holding capacity by its better effectivity in the treatment M_1T_1 in gluing soil particles together. Reports are there as to increased water holding capacity of the soil with corresponding increase in the level of organic carbon and clay(Ramesh *et al.*(2008).

The experiment entitled **Effect of mulches on growth, production and quality of Strawberry (*Fragaria x ananassa*Duch.) cv. Winter Dawn in different growing environments** was conducted during 2013-14 at the Protected Cultivation Unit, College of Horticulture and Forestry, Jhalawar. The results obtained in the present investigation are summarized as under:

6.1 Growth parameters

The treatment M₁T₂: Rice husk+Naturally ventilated polyhouse recorded the maximum crown height (29.33cm), whereas, the minimum crown height (14.89cm) was recorded in treatment (M₀T₁): No mulch+Agro shade net.

Strawberry plants grown in treatment M₁T₂: Rice husk+Naturally ventilated polyhouse recorded the maximum petiole length (20.27cm). On the other hand, the minimum petiole length (7.80cm) was observed in plants grown in M₀T₁: No mulch+Agro shade net.

The maximum number of leaves per plant (97.44) was recorded in treatment M₂T₀: White polythene+Open field conditions. In contrast, lower number of leaves per plant (18.33) was recorded in the treatment M₀T₁: No mulch+Agro shade net.

The maximum E-W spread (51.80cm) and N-S spread (49.88cm) was recorded in plants grown in the treatment M₃T₂: Black polythene+Naturally ventilated polyhouse whereas, minimum E-W spread (26.05cm) was observed in treatment M₃T₁: Black polythene+Agro shade net and minimum N-S spread (24.94cm) was recorded in the treatment M₀T₁: No mulch+Agro shade net.

Strawberry plants in treatment M₁T₂: Rice husk mulch+Naturally ventilated polyhouse recorded maximum fresh weight (235.00g) as well as dry weight (57.28g) in comparison to all other treatment combinations. Plants grown with treatment M₀T₁: No mulch+Agro shade net had significantly minimum plant fresh weight (21.00g). The minimum plant dry weight (5.00g) was recorded in the treatment M₀T₁: No mulch+Agro shade net.

The maximum number of runners per plant (4.00) was observed where plants were grown in treatment M₃T₃: Black polythene+Fan pad system greenhouse, while, the minimum number of runners per plant (0.11) was produced in the treatment M₀T₀: No mulch+Open field.

The total chlorophyll content was maximum (3.26 mgg⁻¹) in plants grown in treatment M₂T₀: White polythene+Openfield, followed by 2.80 mgg⁻¹ in plants those grown in M₃T₂: Black polythene+Naturally ventilated polyhouse. The minimum total chlorophyll content (1.64 mgg⁻¹) was recorded in plants which were grown in treatment M₀T₃: No mulch+Fan pad system greenhouse.

6.2 Production parameters

Combination involving M₃T₃: Black polythene+Fan pad system greenhouse resulted in the earliest initiation of flowering (21.66 days) while, it took more number of days (35.89 days) in the combination M₁T₁: Rice husk+Agro shade net.

The minimum number of days (82.77 days) required to 50 per cent flowering was recorded in M₃T₃: Black polythene+Fan pad system greenhouse and the maximum number of days (112.22 days) was recorded in treatment M₀T₁: No mulch+Agro shade net.

Strawberry plants grown in treatment M₃T₃: Black polythene+Fan pad system greenhouse took the minimum time (26.44 days) for first fruit set, while the plants in treatment M₁T₁: Rice husk+Agro shade net took the maximum days (43.44 days) to first fruit set.

The minimum days (89.00 days) taken to 50 per cent fruit set was recorded in the treatment M₂T₂: White polythene+Naturally ventilated polyhouse and the maximum days (117.26 days) was recorded in M₀T₁: No mulch+Agro shade net.

The minimum days (52.30 days) to first harvest was recorded in treatment M₁T₀: Rice husk+Open field while the plants grown in treatment M₁T₁: Rice husk+Agro shade net took the maximum days (71.89 days) to first harvest.

Strawberry plants grown in treatment M₀T₁: No mulch+Agro shade net had the minimum (88.33 days) productive period. The days taken to final harvest was maximum

(139.44 days) in plants which were grown in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse.

Maximum number of pickings (26.00) was recorded in plants grown in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse condition. The minimum number of picking (2.66) was recorded in plants grown in treatment M₀T₁: No mulch+Agro shade net.

The fruit length in plants grown in treatment M₃T₀: Black polythene+Open field was maximum (54.00mm) than any other obtained in this study while the minimum (27.50mm) was recorded in treatment M₂T₁: White polythene+Agro shade net.

Fruits produced in the treatment M₃T₀: Black polythene+Open field had the maximum fruit width (42.59mm). Fruits grown in the treatment M₂T₁: White polythene+Agro shade net recorded the minimum fruit width (22.37mm).

Maximum length: diameter ratio (1.30) was recorded in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse, M₀T₀: No mulch+Open field and M₀T₁: No mulch+Agro shade net while minimum (1.00) was recorded in treatment M₃T₃: Black polythene+Fan pad system greenhouse.

Fruits in the treatment M₃T₀: Black polythene+Open field recorded the maximum fresh weight (36.74g) and dry weight (2.88g) as compared to other treatments. Treatment M₂T₁: White polythene+Agro shade net and M₁T₁: Rice husk+Agro shade net recorded minimum fresh (7.10g) and dry (0.51g) weight respectively.

The maximum number of fruits per plant (39.66) was recorded in plants grown in the treatment M₃T₂: Black polythene+Naturally ventilated polyhouse. The minimum number of fruits per plant (4.66) was recorded in plants grown in treatment M₀T₁: No mulch+Agro shade net.

The strawberry plants grown in treatment M₃T₀: Black polythene+Open field resulted in maximum fruit yield per plant (536.55g) while the minimum fruit yield per plant (29.22g) was recorded from the treatment M₀T₁: No mulch+Agro shade net.

6.3 Quality parameters

The strawberry plants grown in treatment M₃T₀: Black polythene+Open field had fruits with the maximum TSS (7.30°B) while the minimum (6.00°B) was recorded in treatment M₀T₁: No mulch+Agro shade net.

The maximum (1.90 per cent) titratable acidity was observed in fruits grown in treatment M₃T₃: Black polythene+Fan pad system greenhouse while the minimum (1.45 per cent) was found in fruits grown in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse.

Maximum TSS/acid ratio (4.97) was noted in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse. The minimum TSS/acid ratio (3.49) was recorded in treatment M₃T₃: Black polythene+Fanpad system greenhouse.

The maximum total sugar content (5.15 per cent) was recorded in fruits grown in treatment M₃T₀: Black polythene+Open field, whereas the minimum total sugars content (2.10 per cent) was found in fruits grown in the treatment M₀T₂: No mulch+Naturally ventilated polyhouse.

The maximum reducing sugar (4.06 per cent) was found in fruits produced in treatment M₃T₀: Black polythene+Open field while minimum (1.51 per cent) was recorded in treatment combination M₀T₂: No mulch+Naturally ventilated polyhouse.

The maximum juice content (96.10 per cent) was observed in fruits that were grown in the treatment M₃T₀: Black polythene+Open field, while the minimum juice percentage (65.11 per cent) was recorded in treatment M₁T₀: Rice husk+Open field.

The maximum vitamin C (52.54 mg100g⁻¹) was recorded in treatment M₃T₀: Black polythene+Open field while minimum (39.20 mg100g⁻¹) was recorded in treatment M₁T₀: Rice husk+Open field.

The maximum total anthocyanin content (45.51 mg 100 g⁻¹) was recorded in plants grown in treatment M₃T₂: Black polythene+Naturally ventilated polyhouse and the minimum total anthocyanin content (28.75 mg 100 g⁻¹) was recorded in treatment M₀T₃: No mulch+Fan pad system greenhouse.

Fruits scoring maximum sensory score (8.35) were those grown in the treatment M₃T₀: Black polythene+Open field while minimum score (6.27) was recorded in fruits produced in the treatment M₀T₃: No mulch+Fan pad system greenhouse.

6.4 Root growth parameters

Significant differences with respect to the root weight of strawberry among various treatment combinations have been observed. The maximum fresh weight (37.76 g) of root was recorded in strawberry plants grown in treatment M₃T₀:Black polythene+Open field, while the minimum fresh weight (1.68g) of root was observed in the treatment M₂T₁:White polythene+Agro shade net. Also, the maximum dry weight of root (7.32g) was recorded in treatment M₃T₀:Black polythene+Open field and the minimum (0.80g) in treatment M₂T₁: White polythene+Agro shade net.

The maximum (45.55 cubic centimetre) and minimum (6.14 cubic centimetre) root volume was observed in the treatment M₃T₀: Black polythene+Open field and M₀T₃: No mulch+Fan pad system greenhouse, respectively.

The minimum root length (11.33 cm) was seen in the treatment M₀T₁: No mulch+Agro shade net while the maximum root length (28.22 cm) was recorded in plants grown in the treatment M₃T₀: Black polythene+Open field.

The the maximum number of roots (190.55 and 176.11, respectively, for thin and thick roots) was recorded in the treatment M₃T₀: Black polythene+Open field, while, the minimum (26.11 and 31.66, respectively, for thin and thick roots) was observed in treatment M₃T₁: Black polythene+Agro shade net mulch.

The maximum root:shoot ratio (0.46) was observed in plants grown in treatment M₁T₀: Rice husk+Open field, while the minimum (0.11) was recorded in treatment M₂T₃: White polythene+Fan pad system greenhouse.

6.5 Soil parameters (after experiment)

The maximum recorded value of pH (7.49) was noted in treatment M₃T₀: Black polythene+Open field and the minimum recorded value of pH (6.46) in the treatment M₂T₂: White polythene+Naturally ventilated polyhouse.

The maximum EC (0.91 dSm⁻¹) was recorded in the treatment M₀T₂: No mulch+Naturally ventilated polyhouse. The minimum EC (0.35dSm⁻¹) was recorded from M₃T₀: Black polythene+Open field treatment.

Maximum organic carbon (0.76 per cent) was observed in treatment M_1T_1 : Rice husk+Agro shade net and the minimum (0.43 per cent) in treatment combination of White polythene+Naturally ventilated polyhouse (M_2T_2) and M_2T_3 : White polythene+Fan pad system greenhouse

Maximum available nitrogen (734 kg ha^{-1}) was recorded from the treatment M_1T_1 : Rice husk+Agro shade net while the minimum (415 kg ha^{-1}) was found in treatment M_2T_2 : White polythene+Naturally ventilated polyhouse and M_2T_3 : White polythene+Fan pad system greenhouse.

Maximum available phosphorous (58.13 kg ha^{-1}) was recorded in the treatment M_1T_2 : Rice husk+Naturally ventilated polyhouse and the minimum (25.01 kg ha^{-1}) in treatment M_0T_3 : No mulch+Fan pad system greenhouse.

The maximum available potassium (513 kg ha^{-1}) was observed in the treatment M_3T_2 : Black polythene+Naturally ventilated polyhouse, while, the minimum available potassium (402 kg ha^{-1}) was recorded in treatment M_3T_1 : Black polythene+Agro shade net.

Maximum water holding capacity (53.90 per cent) was noted in the treatment M_1T_1 : Rice husk+Agro shade net while water holding capacity was minimum (23.12 per cent) in treatment M_2T_2 : White polythene+Naturally ventilated polyhouse.

On the basis of results obtained from the field experiment entitled “**Effect of mulches on growth, production and quality of Strawberry (*Fragaria x ananassa*Duch.) cv. Winter Dawn under different growing environments**”, following conclusions can be drawn:

7.1 Growth parameters

Treatment M₁T₂: Rice husk+Naturally ventilated polyhouse had the maximum crown height (29.33cm), petiole length (20.27cm), fresh weight (235.00g) and dry weight (57.28g) weight of plant.

Maximum number of leaves per plant (97.44) and total chlorophyll content (3.26mgg⁻¹) was recorded in the treatment M₂T₀: White polythene+Open field.

Plant E-W spread and N-S spread was observed maximum (51.80cm and 49.88cm, respectively) in the treatment M₃T₂: Black polythene+Naturally ventilated polyhouse.

As regard to runner production, treatment M₃T₃: Black polythene+Fan pad system greenhouse was found best in which the runner production was 4.00 per plant which was as minimum as 0.11 per plant in M₀T₀: No mulch+Open field.

7.2 Production parameters

Treatment M₃T₀: Black polythene+Open field produced maximum fruit length (54.00mm), fruit width (42.59mm), fresh weight (36.74g) and dry weight (2.88g) of fruit and fruit yield per plant (536.55g).

Minimum days to first flower initiation (21.66 days), 50 per cent flowering (82.77 days) and first fruit set (26.44 days) was recorded in the treatment M₃T₃: Black polythene+Fan pad system greenhouse.

Maximum harvest period (139.44 days), number of pickings (26.00), length:diameter ratio (1:30) and number of fruits per plant (39.66) were observed in the treatment M₃T₂: Black polythene+Naturally ventilated polyhouse.

Minimum number of days (89.00 days) required to 50 per cent fruit set was noted in the treatment M₂T₂: White polythene+Naturally ventilated polyhouse, whereas minimum number of days (52.30 days) to first harvest was recorded in the treatment M₁T₀: Rice husk+Open field.

7.3 Quality parameters

Treatments M₃T₀: Black polythene+Open field recorded maximum TSS (7.30°B), Vit.C content (52.54mg100g⁻¹), total (5.15 per cent) and reducing sugar (4.06 per cent, respectively), juice content (96.10 per cent) and overall sensory score (8.35).

Minimum titratable acidity (1.45 per cent), maximum TSS/acid ratio (4.97) and maximum anthocyanin content (45.51 mg100g⁻¹) was recorded in the treatment M₃T₂: Black polythene+Naturally ventilated polyhouse.

7.4 Root growth parameters

Maximum fresh weight (37.76g) and dry weight (7.32g) of roots, root volume (45.55 cubic centimeter), number of thin (190.55) and thick (176.11) roots and root length (28.22cm) was recorded in the treatment M₃T₀: Black polythene+Open field.

Root: shoot ratio was observed maximum (0.46) in the treatment M₁T₀: Rice husk+Open field.

7.5 Soil parameters (after experiment)

Maximum recorded pH value (7.49) and minimum EC (0.35dSm⁻¹) was found in the treatment M₃T₀: Black polythene+Open field.

Treatment M₁T₁: Rice husk+Agro shade net had maximum OC (0.76 per cent), available N (734 kg ha⁻¹) and water holding capacity (53.90 per cent).

Available P (58.13 kg ha⁻¹) and available K (513 kg ha⁻¹) were recorded maximum in the treatment M₁T₂: Rice husk+Naturally ventilated polyhouse and M₃T₂: Black polythene+Naturally ventilated polyhouse, respectively.

Summarizingly, from production point of view, treatment M₃T₀: Black polythene+Open field was found better in which the production was 536.55g per plant. It was higher by 5.13, 1.97 and 1.58 per cent than those harvested maximally in the treatments M₃T₁: Black polythene+Agro shade net, M₃T₃: Black polythene+Fan pad system greenhouse and M₃T₂: Black polythene+Naturally ventilated polyhouse, respectively.

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