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Growth and Soil Health Influenced by Different Mulching and Irrigation Levels in Sunflower during Summer

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ABSTRACT: Optimizing water usage is essential for achieving higher crop and water productivity. In this study, conducted in 2019, we aimed to assess water management strategies to enhance productivity and profitability in sunflower cultivation. We implemented various combinations of mulching and irrigation levels, which included three mulch types: no mulch, straw mulch and polythene mulch, along with four levels of irrigation: critical stages, 0.8, 1.0 and 1.2 IW/CPE. Results revealed that polythene mulch led to highest values for growth parameter such as plant height, dry matter accumulation (DMA), number of leaves, stem diameter, SPAD values and nutrient content in grain and stover. Additionally, soil microbial biomass carbon (SMBC) and enzymatic activity were most pronounced in plots with straw mulch. Among the different irrigation schedules, 1.2 IW/CPE level demonstrated superior performances, exhibiting higher growth attributes, nutrient content in both grain and stover and total uptake of nutrients. Furthermore, the application of irrigation at 1.0 IW/CPE resulted in highest SMBC and enzymatic activity in soil. This research sheds light on the potential benefits of polythene mulch and optimized irrigation schedules for enhancing sunflower cultivation in the Tarai region of Uttarakhand, with implications for improved crop yields and soil health.

Keywords: Irrigation Level, IW/CPE ratio, Mulch, Soil health, Water productivity.

INTRODUCTION

Sunflower holds a significant global presence as a crucial oilseed crop renowned for its high-quality oil and dietary fiber, which offer substantial health benefits to humans. Sunflower (*Helianthus annuus* L.) belongs to the family Asteraceae. Helianthus genus contains 65 different species (Andrew *et al.*, 2013). The name *Helianthus*, being derived from *helios* (the sun) and *anthos* (a flower), has the same meaning as the English name Sunflower, which has been given these flowers from a supposition that they follow the sun by day, always turning towards its direct rays. The sunflower that most people refer to is *H. annuus*, an annual sunflower. Sunflower is the world‘s fourth largest oil-seed crop and its seeds are used as food and its dried stalk as fuel. It is already been used as ornamental plant and was used in ancient ceremonies (Harter *et al.*, 2004; Muller *et al.*, 2011). The sunflower plant has diverse applications, including medicinal uses for pulmonary conditions. It also serves as a source for dyes used in textiles, body painting, and various decorations. Moreover, sunflowers are utilized in the industrial sector for producing paints and cosmetics. The sunflower plant originated in eastern North America. It is thought to have been domesticated around 3000 B.C. by Native Americans. In the late 1800s, the sunflower was introduced in the Russian Federation where it became a food crop and Russian farmers made significant improvements in the way that the sunflower was cultivated. According to (FAOSTAT, 2018) Russia Federation ranked first producing ca. 9.7 millions of tons of sunflower seeds or 26% of the world total. Ukraine and Argentina ranked second and third place with 8.6 and 3.6 tons of sunflower seeds, respectively. In certain nations like India and South Africa, the cultivation of sunflowers may present a more competitive option compared to other crops such as maize, soybean, and sorghum (Vijayakumar *et al.*, 2016).

The importance of water in plants arises from its role in supporting photosynthesis, regulating temperature via evaporative cooling, maintaining structure through cell turgor pressure (i.e., in maintaining leaf orientation), and transporting nutrients into and throughout the plant, thereby supporting its growth. While irrigation guarantees crop growth in regions where rainfall is insufficient to support crop growth and yield, it must be scheduled properly, lest crops suffer water stress at a critical growth stage, or excess water applied that leads to ponding, waterlogging, runoff and/or deep seepage, thereby leaching applied nutrients and polluting water bodies. Over the last few decades, a number of methods for scheduling and quantifying the required depth of individual irrigation applications have been proposed. A good irrigation schedule, achieved through well informed IS criteria, can provide significant irrigation water savings, whether it be for landscape applications, agricultural crop yield and quality, or turf quality. This could be addressed primarily with better water management through scientific irrigation scheduling (irrigation water depth (IW) to cumulative pan evaporation (CPE) ratio, i.e., IW/CPE) which will boost both production and productivity of mustard as well as minimize the risk associated with climate change. Kadasiddappa *et al.* (2018) reported that sunflower plants exhibited highest plant height at irrigation applied 100% Epan compared to 80% Epan. Mulching is an essential process in agricultural production, used primarily to protect the environment along with improving the soil. It could be categorized into inorganic and organic mulching categories depending on the type of materials used. Mulching has potential to increase soil moisture, stop the loss of nutrients from the soil, and No mulch crop pests and diseases. it may also alter the biological properties of the soil, have a detrimental effect on its sustainability and quality, and even produce soil alkalization, which could harm plants. Organic mulching, on the other hand, is distinct since it primarily consists of plant remnants, which have been shown to be healthier for soil health.

Mulching with different materials has been demonstrated to reduce water evaporation (Li *et al.*, 2013; Pabin *et al.*, 2003), improve fallow efficiency and increase the amount of stored soil water available for plant use (Wang *et al.*, 2001), and reduce salt build-up in the soil (Pang *et al.*, 2010). The crop residues placed on the soil surface shade the soil, reduce unproductive water evaporation, and enhance available water capacity, moisture retention and aggregate stability observed by Mulumba and Lal (2008). Mulching with crop residues improved water-use efficiency by 10–20% as a result of reduced soil evaporation and increased plant transpiration Deng *et al.*, (2006). Havlin *et al.*, (1990) showed that returning crop residues to the soil has a beneficial effect on building soil organic carbon, which thereby improves soil quality and productivity. In the agro-ecosystem, soil microorganisms were crucial to maintaining structure and cycling nutrients. The diversity of soil microbes played a role in the movement of materials and energy within the soil ecosystem. The physicochemical characteristics of the soil can vary during the mulching process, which can impact the microbial community's structure and metabolic activity.

The plastic mulch help in reducing water loss by evaporation, decreasing salt accumulation, conserving soil moisture, promoting crop growth and increasing crop water use efficiency have been widely reported (Deng *et al.*, 2006; Liu *et al.*, 2009). The individual use of plastic mulch performed better than the individual use of straw layer burial for reducing salt accumulation in the root zone, but the effectiveness was greater when both treatments were combined. plastic mulching can increase crop yield by 20%–50% (Liu *et al.*, 2014; Liu *et al.*, 2014), because it reduces nitrogen leaching, improves tillage quality (Luo *et al.*, 2010), increases soil temperature, and reduces soil water evaporation, thereby influencing the hydrothermal conditions of the soil (Qin *et al.*, 2013). Therefore, in order to study of best mulching with different irrigation levels of spring sunflower, present investigation was carried out.

MATERIAL AND METHOD

Field experiment was carried out at Instructional Dairy Farm, Nagla, G. B. Pant University of Agriculture and Technology, Pantnagar in spring season 2019 to study the **"**Influence of mulch and irrigation levels on growth and soil health in summer sunflower". The experiment location was situated at an altitude of 243.84 meters above mean sea level in the Tarai section of the Shivalik range of the Himalayas, between latitude 29° N and longitude 79.3° E. The soil had a slightly silty clay loam texture, a granular structure, a soil pH were 7.16, an EC of 0.190 dS/m, a percentage of organic carbon of 0.47 percent, and accessible nitrogen, phosphorus, and potassium concentrations that were 282.51, 28.16, and 235.00 kg/ha, respectively. The experiment was consisted by three mulches: M_1: No mulch, $M_{2:}$ Straw mulch and M_3: Polythene mulch and four irrigation levels I_1: critical stages, I_2 - 0.8, I_3 - 1.0 and I_4 - 1.2 IW/CPE ratio replicated with thrice. The plant growth attributes were studied based on randomly selected five plants from each plat at different growth stages, while the yield was based on net plot and converted into hectare basis. The chlorophyll content is an index of greenness was measured by SPAD meter.

The variety of field was DRSH-1 and crop was sown on 23 March 2019. Seed rate and spacing of growing the crop were 5 kg ha^{-1} with 60 cm × 20 cm spacing, respectively. Thinning operation was done during 15–20 days after sowing (DAS) in each row to maintain proper plant to plant spacing of 10 cm. The recommended dose of fertilizer i.e. 120:60:40 NPK (kg/ha) was applied at sowing through chemical fertilizers i.e. urea, NPK (12:32:16) as an N, P and K source and their calculated dose was applied to treatments. For effective weed management, pre-emergence application of Pendimethalin at 1.0 kg a.i. ha^{-1} was used. Foliar spray of Monocrotophos at 0.5 kg ha^{-1} was done to prevent aphid infestation at flowering stage. Harvesting of the crop was done on 21 June 2019. Polythene mulch and oat straw at 6t ha^{-1} was applied in flat bed plots under mulching treatment at 25 DAS, while, under no-mulch No mulch was applied. Mulch was uniformly spread in between the rows of crop in flat bed. Details of the experimental design are presented in Fig. 2. A common irrigation was applied at 7-8 DAS during research experiment, respectively to ensure proper germination as well as establishment of the crop irrespective of cumulative pan evaporation readings. Afterward the irrigation was scheduled on the basis of the ratio of irrigation water depth (IW) to cumulative pan evaporation (CPE) values recorded from USWB Class-1 open pan evaporimeter maintained at the crop weather observatory GBPUAT, Pantanagar. The CPE values were adjusted for the effective rainfall occured during the irrigation intervals. In this approach a known amount of irrigation water (IW) is applied when cumulative pan evaporation CPE reaches a predetermined level. Pan evaporation denoted the water loss because of evaporation from an open pan evaporimeter. The total amount of irrigation water (IW) was applied in each irrigation was 50 mm during experimentation.

Soil sampling. Soil for microbiological analysis was sampled in all plots. Soil samples were collected in the crop rhizosphere (in depth of 30 cm) at the flowering stage of sunflower. Plants were excavated from four random 0.5-m lengths of a row from each plot. Loose soil was shaken off the roots, and soil that adhered strongly to the roots was carefully brushed off and kept as rhizosphere soil. Apart from those samples for dehydrogenase activity, soils were air-dried at 308 °C for 48 h, sieved to 52 mm and stored at 48C. For dehydrogenase activity, soils were sieved to 52 mm as fresh sample (field moisture) and then stored at 48°C.

Microbial biomass carbon. MBC was determined on a 15-g oven-dry equivalent field-moist soil sample (sieved to 55 mm) by the chloroform fumigation extraction method. In brief, organic C from the fumigated (24 h) and non-fumigated (No mulch) soil was quantified using a TOC/TN analyzer (Model: TOC-Vcpn and TNM-1, Shimadzu Corp., Kyoto, Japan). The non-fumigated No mulch values were subtracted from the fumigated values. Biomass C was determined using the following formula: MBC ¼ ð Þ C in fumigated soil C in unfumigated soil =k.

RESULT AND DISCUSSION

Effect of mulching and irrigation levels on growth attributes

Data pertaining to growth parameters are presented in Table 1. The results show that, growth parameters of sunflower are significantly influenced by mulch and different irrigation levels. Among different mulching materials highest growth parameters (2.17, 23.35, 42.97, 174.46, 21.78) was recorded with polythene mulch compared to rest to straw mulch. The higher plant height, SPAD values, numbers of leaves/plant might be due to higher moisture availability and better nutrient removal by the crop which in turn resulted more assimilation of photosynthetic. The higher growth attributes observed under polythene mulch can likely be attributed to the improved microclimate it provided, which created suitable conditions for promoting increased plant growth (Dawar and Pal, 2021). This outcome was a result of maintaining favorable soil moisture levels under polythene mulch, as indicated by the higher consumptive water use. This, in turn, led to better crop growth, as evidenced by greater plant height and a higher number of leaves, ultimately resulting in enhanced photosynthesis. This result might be due to high irrigation frequency maintained moisture content in the root zone which helped in nutrient uptake and maintain water balance in plant resulting proper metabolic and structural activities and finally higher dry matter yield and stem diameter (Dawar *et al.*, 2023: Meena *et al*. 2017). It is well known fact that optimum soil moisture regime maintained at 1.2 IW/CPE ratio caused better plant growth and development including photosynthetic area and dry matter production (Pradhan *et al.*, 2018; Dawar and Pal 2021). The greater stem diameter observed can be attributed to an increased rate of cell division and cell enlargement under sufficiently moist soil conditions. Film and straw mulching also impact on significantly increased plant height and stem diameter (Zhao, *et al.*, 2014). Additionally, this was facilitated by higher photosynthetic activity, coupled with adequate soil moisture, which allowed the plant to accumulate more dry matter observed (Situmeang *et al*. 2017; Dawar and Pal, 2021). Among various irrigation levels highest growth parameters of sunflower was recorded with 1.2 IW/CPE ration compared to rest of the treatments, which is significantly different from each other. There was no significant difference was observed in interaction effect of mulch and different irrigation levels.

Table 1: Growth parameters of sunflower is influenced by different mulch and irrigation levels at 60 DAS.

Treatments	Stem diameter (cm)	No of leaves	DMA(g/plant)	Plant Height (cm)	SPAD Values
Mulching					
No mulch	1.96	22.01	36.00	161.25	19.57
Straw mulch	2.05	23.01	39.79	171.84	21.01
Polythene mulch	2.17	23.35	42.97	174.46	21.78
Sem±	0.12	0.88	0.91	3.66	0.69
LSD(p=0.05)	NS	3.45	3.56	14.38	2.73
Irrigation levels					
Critical stages	1.42	18.80	34.78	157.07	19.15
0.8 IW/CPE	2.30	23.90	39.63	164.65	20.81
1.0 IW/CPE	2.39	24.10	40.97	176.17	21.12
1.2 IW/CPE	2.12	24.35	42.98	178.85	22.07
Sem±	0.11	0.72	1.58	6.68	0.82
LSD(p=0.05)	0.33	2.13	4.71	19.86	2.42

This result might be due to high irrigation frequency maintained moisture content in the root zone which helped in nutrient uptake and maintain water balance in plant resulting proper metabolic and structural activities and finally higher dry matter yield and stem diameter (Dawar *et al.*, 2023: Meena *et al.*, 2017). It is well known fact that optimum soil moisture regime maintained at 1.2 IW/CPE ratio caused better plant

growth and development including photosynthetic area and dry matter production (Pradhan *et al.*, 2018; Dawar and Pal 2021). These results are supported by Thakuria *et al.*, (2004) who observed that, plant height, leaf number, dry matter accumulation, at various intervals in sunflower was improved under irrigated condition. Tan *et al.*, (2000) reported that full and limited irrigation applied at different growth stages significantly increased plant height in sunflower.

Effect of mulching and irrigation levels soil microbial carbon and enzymes

The soil microbial carbon (SMBC) and enzymatic activity in sunflower were differed significantly to different mulching and irrigation levels (Fig. 1). Among the different mulching, straw mulch found significantly higher SMBC and enzymatic activity compared to polythene mulch and No mulch except alkaline phosphatase (ALP) which was found similar to polythene mulch. Under straw mulch found significantly higher SMBC and Soil enzymatic activity which might be due to organic residues, circulation of nutrients, as well as forming organic matter and soil structure (Vidyashree and Arthanari, 2022). This might be due to mulches had enough soil-available nutrients that, as they decomposed, altered the pH of the soil and increased the number of microorganisms Pal *et al.*, (2013). Various irrigation levels significantly influenced soil microbial carbon and enzymatic activity. The significantly higher enzymatic activity observed when irrigation applied at 1.2 IW/CPE ratio compared to critical stages while 0.8 and 1.0 IW/CPE found similar to each other. The SMBC recorded significantly higher under irrigation applied at 1.0 IW/CPE that was at par with 0.8 IW/CPE and lowest SMBC indicated under critical stages. The increase in irrigation levels increased soil enzymatic activity resulted the increase in soil moisture accelerated the mobility of the reactants, which could provide a good reaction environment for the enzymatic reaction and consequently enzymatic activity and SMBC was increased (Bandyopadhyay *et al.*, 2010). Increased water significantly increased the activity of soil protease and dehydrogenase, while acid phosphatase activity in topsoil increased more significantly, and within the appropriate range, appropriate fertilization along with increased irrigation amount maximized enzyme activity (Zhou *et al.*, 2013).

Effect of mulching and irrigation levels NPK Content and total NPK uptake:

NPK Content. NPK content in grain and stover increased under different mulching. Among the different mulching polythene mulching recorded significantly higher NPK content in grain and stover over straw mulching and No mulch, although K content grain and stover observed statically similar to straw mulch. Likewise irrigation levels also gave the significant result with different irrigation schedules, NPK content resulted higher irrigation applied at 1.2 IW/CPE ratios compared to critical stages and 0.8 IW/CPE ratios but it was similar with 1.0 IW/CPE ratio (Table 2).

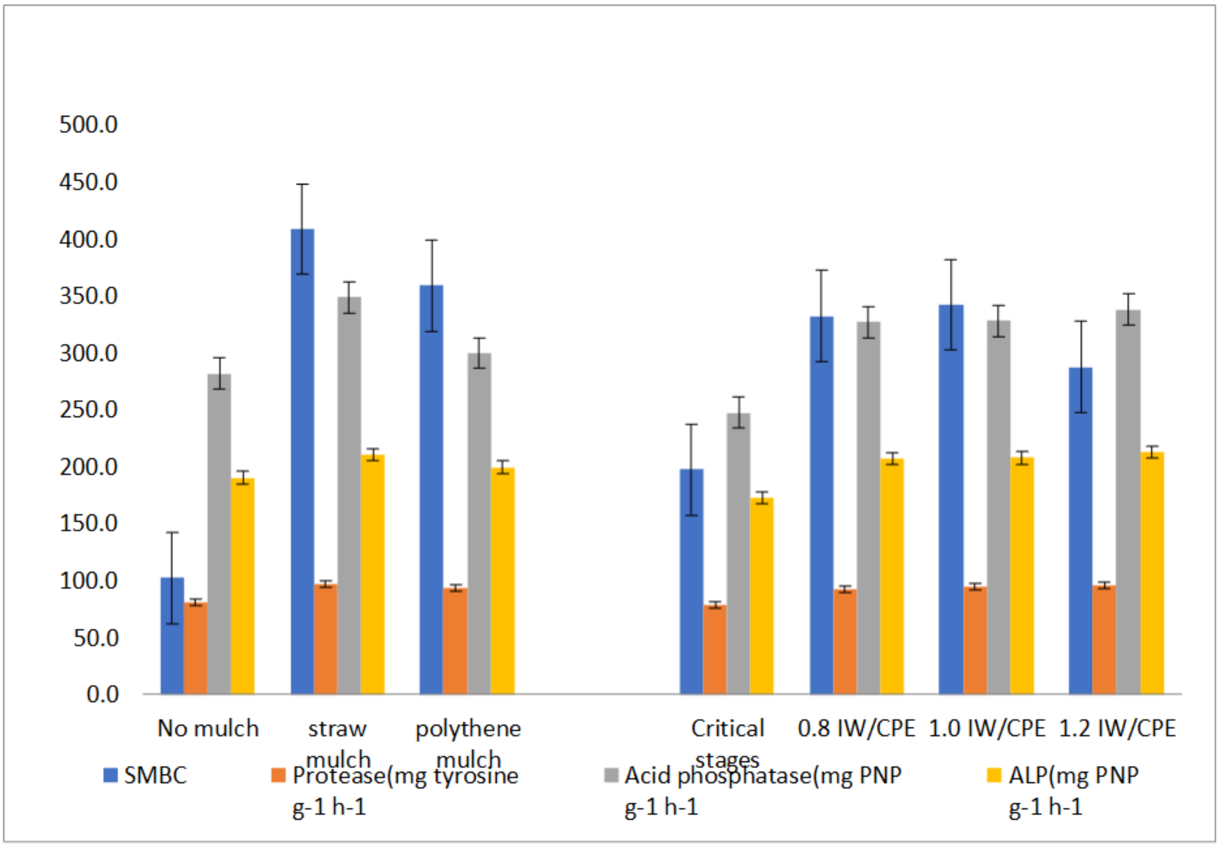

Fig. 1. SMBC, Protease, Acid phosphatase and ALP is influenced by mulch and different irrigation levels at flowering stage.

Total NPK uptake. Data on total NPK uptake of sunflower as influenced by mulching and irrigation levels have been mentioned in Table. Mulching had a significant effect on total NPK uptake. The polythene mulching recorded significantly higher total NPK uptake over straw mulch and No mulch.

Among the various levels of irrigation, irrigation level 1.2 resulted higher total NPK uptake recorded over remaining irrigation levels. Mulching can help retain nutrients in the soil by reducing the leaching of nutrients due to rain or irrigation. This is particularly important for mobile nutrients like nitrogen. The nutrient content and uptake was higher under mulching might be due to favorable microclimatic effect of mulching and release of these nutrients after the decomposition of the organic residues in soil, which replenished the nutrient pool in real time. Mulch acts as a barrier that prevents these nutrients from being washed away. Straw mulches or wood chips, can gradually release nutrients into the soil as they decompose. Mulch can enhance soil microbial activity. Microbes break down organic mulch material, which can release nutrients into the soil. This can lead to improved nutrient availability for plants. Mulch can suppress weed growth. Weeds compete with cultivated plants for nutrients, so reducing weed competition can indirectly improve nutrient availability to the desired plants. The higher uptake of nutrients due to higher dry matter production and presence of higher nutrient content. Significantly higher utilization of nutrients resulted in higher nutrient uptake in affirmation with Lehoczky *et al.* (2006). The increase nutrient concentration in grain and stover with increase irrigation levels might be due to increase the solution concentration of nutrients. The increase in uptake of nutrients by sunflower crop appears due to the cumulative effect of increased seed and stover yields. The application of N, P and K might have increased their concentration in soil solution which increased their availability and uptake by plant (Thanki *et al.*, 2014).

Table 2. Effect of mulch and irrigation schedules on NPK content and total uptake.

Treatment	N content (%)		Total N uptake (Kg/ha)	P content (%)		Total P uptake (Kg/ha)	K content (%)		Total K uptake (Kg/ha)
	Grain	Stover		Grain	Stover		Grain	Stover	
Mulching									
No mulch	2.85	0.56	115.1	0.62	0.35	41.9	0.73	1.44	125.4
Straw mulch	2.86	0.59	128.0	0.64	0.36	45.7	0.76	1.47	131.2
Polythene mulch	2.91	0.66	144.5	0.68	0.39	53.8	0.78	1.49	148.1
Sem±	0.01	0.01	2.9	0.01	0.00	1.1	0.00	0.01	2.8
LSD(p=0.05)	0.02	0.04	11.5	0.02	0.02	4.5	0.02	0.02	11.3
Irrigation levels									
Critical stage	2.83	0.57	117.7	0.63	0.35	42.6	0.73	1.44	125.4
0.8 IW/CPE	2.86	0.59	125.4	0.64	0.36	45.4	0.75	1.47	134.2
1.0 IW/CPE	2.88	0.61	130.4	0.66	0.38	47.5	0.77	1.47	132.2
1.2 IW/CPE	2.89	0.65	143.4	0.69	0.39	53.1	0.79	1.48	147.9
Sem±	0.00	0.01	1.5	0.01	0.01	0.6	0.01	0.01	1.8
LSD(p=0.05)	0.01	0.02	4.4	0.02	0.02	1.8	0.02	0.02	5.5

CONCLUSIONS

The experimental results indicated that polythene mulch with 1.2 IW/CPE ratio gave significantly higher plant height, dry matter accumulation, stem diameter, number of leaves, SPAD values and soil chemical properties while straw mulch with 1.0 irrigation schedules gave beneficial SMBC and soil enzymatic activity. Therefore, it is concluded that sunflower may be grown under straw mulch with 1.0 IW/CPE irrigation schedules for economical way.

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Conflicts of Interest. The authors declare no conflict of interest.

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