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## Effect of Sowing Dates on Lettuce Yield, Grown in Open Field and Partial Shade

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### Abstract

The lettuce (*Lactuca sativa* L.), variety 'Large Speed' was grown in two growing conditions (open field and partial shade) at different sowing and transplanting dates, and their effect was studied. The seeds of lettuce were sown on six different dates i.e., 24<sup>th</sup> December 2020, 8<sup>th</sup> January, 23<sup>rd</sup> January, 7<sup>th</sup> February, 22<sup>nd</sup> February, and 9<sup>th</sup> March 2021. The results showed that the growing conditions and sowing dates significantly affected the growth and yield of the lettuce crop. Regarding the growing conditions, the plants grown in the open field produced maximum chlorophyll content, number of leaves plant<sup>-1</sup>, head diameter, head fresh weight, head dry weight, leaf Area, number of seeds plant<sup>-1</sup>, seed yield, and root length plant<sup>-1</sup>. On the other hand, maximum head height plant<sup>-1</sup>, days to flowering, days to seed production, plant height, and better taste were recorded in partial shade. In terms of sowing dates, maximum chlorophyll content, number of leaves plant<sup>-1</sup>, head height, head diameter, head fresh weight, head dry weight, leaf area, number of seeds plant<sup>-1</sup>, seed yield, root length, taste, days to flowering, days to seed production and plant height were recorded for the plants of first sowing and transplanting date (24<sup>th</sup> Dec). These parameters decreased with delayed sowing and transplanting.

**Keywords:** Sowing Dates, Lettuce, Growing Condition, Open Field, Partial Shade, *Lactuca Sativa*

### Introduction

Lettuce (*Lactuca sativa* L.) is a major leafy vegetable plant that belongs to the family Asteraceae. It is one of the most consumed, short-seasoned, and economically important vegetables throughout the world [1]. The total cultivated area was 1,227,358 hectares with a production of 27 million tons annually worldwide [2]. It is native to Europe, Asia, and northern Africa and has been in cultivation for 5000 years [3]. Lettuce contains bioactive compounds that lower cholesterol and enhance the antidiabetic response of the body and contain antioxidants, Vitamin A, and anti-carcinogenic phytochemicals [4]. Being a good source of fiber, iron, folate, potassium, and vitamins, it is needed for the body's normal functioning [5]. Lettuce is a cool-loving plant that grows at a day temperature of 18 to 25°C and at night temperatures ranging from 10 to 15°C [6]. It is sensitive to day length and high temperature. Long days and high temperatures trigger premature flower initiation causing bolting, thus shifting the plant from a vegetative to a reproductive state [4]. Its production in the summer season reduces and becomes a challenge for the growers [7]. Increasing light intensity harms its leaf quality failing in overall production [8].

### Growing Conditions

Growing conditions, in addition to genotype, can have a considerable impact on the amount of various phenolic compounds in lettuce, indicating that growing lettuce in an open field can improve its health-promoting properties. Oh *et al.*, (2011) [9]. The ability to produce throughout the year is one of the major goals of vegetable crop production around the world. Aspects of the environment such as air and soil temperatures, as well as CO<sup>2</sup> air concentration, must be artificially controlled to achieve this goal. Growing areas in protected cultivation are trending towards mild climatic regions of the world, where plants can grow without artificial control of the environment, as production costs rise as a

result of these procedures [7]. In Peshawar's climate, its production beyond mid-February decreases because of high temperature and light intensity, which may result in bolting, the bitterness of leaves, leaf tip-burn, and stem elongation. To minimize the effects of high temperature and high radiation crops like lettuce can be grown under screens [10]. Using shade cloth is helpful to create a microclimate that lowers the air temperature and creates a good impact on relative humidity [11,12]. Shade cloths are also effective in the production of taller plants, increasing leaf area (desirable for leafy vegetables), and cut-flower production [13]. Changing growing and transplanting time has shown good results in crops regarding good quality of fruits and production of seeds [14]. It is also helpful in reducing bolting in lettuce, which is a major problem for growers.

### Sowing Dates

The ability to produce round the year is one of the major goals of vegetable crop production around the world [15]. Being a nutritional and good commercial crop, lettuce has gained the interest of growers. To meet the demands of the population, it needs a further understanding of growing this crop on different sowing dates to extend its availability. As its production is restricted to the winter season and its availability becomes difficult when the summer season approaches. Among the several factors, sowing time has an important role in good and marketable production. Earlier sowing results in higher crop biomass. However, there is an increased risk of frost damage, and lodging at the end of the season and as a result, the flowering and pod setting stage is heavily affected [16]. The optimum time of sowing greatly depends upon the plant, variety, and location [17].

This study was conducted to check the outcome of different growing conditions and sowing dates on lettuce yield and growth with the following objectives. To study the effect of sowing dates on lettuce quality and yield under Peshawar conditions. To observe the growth of lettuce in the open field in comparison with partial shade. To see whether any interaction exists between the growing conditions and the sowing time of lettuce.

### Materials and Methods

#### Experiment design and Plant culture and Transplantation

A study entitled "effect of sowing dates on lettuce yield, grown in the open field and partial shade" was conducted in the Ornamental Nursery, Department of Horticulture, The University of Agriculture, Peshawar during 2020-2021. A common lettuce variety 'Large Speed' was studied in the experiment. The research was conducted in a randomized complete block design (RCBD) with three replications in a split-plot arrangement. Two factors were studied in the experiment i.e., growing conditions (Factor A) and sowing dates (Factor B). A 15 days interval was kept between seed sowing and its transplantation.

Seeds were grown first in media-filled pots for nursery raising for each sowing dates. The pots were sprinkled with water immediately. To protect the seeds from the harsh environment and to give them optimum humidity the pots were then kept in the plastic tunnel. When the seedlings reached the 3-4 leaf stage, they were transplanted to 22x30 cm plastic growing bags, filled with silt, leaf manure, and animal manure, mixed at a ratio of 2:1:1. When the plants achieved the appropriate vegetative growth, half of them were harvested for destructive analysis, and half were left for seed production in both growing conditions. Daily light intensity, temperature, and humidity were recorded using a light meter (TES 1332 Digital Light Meter) and a hygrometer (Temperature Humidity Meter HTC-2, China). Crop management practices such as fertilizer application, weeding, pest management, and hoeing were maintained throughout the trial.

### Sowing Dates

The lettuce seeds were sown on six sowing dates with 15 days intervals (starting on 24<sup>th</sup> Dec 2021 and ending on 9<sup>th</sup> March 2022) at the Ornamental Nursery of the Department of Horticulture, The University of Agriculture, Peshawar, Pakistan. The seeds on three to four leaf stage maturity, were transplanted on 21<sup>st</sup> Jan, 5<sup>th</sup> Feb, 20<sup>th</sup> Feb, 7<sup>th</sup> March, 22<sup>nd</sup> March and 6<sup>th</sup> March respectively into plastic growing bags and irrigated immediately. The bags were then kept in their respective experimental conditions *i. e.*, Open field and Partial shade as per requirement.

### Environmental Data Collection

Temperature, humidity, and light intensity were taken daily as mentioned above. The light intensity, temperature, and humidity recorded during the trial are given in figure 2.1, 2.2, and 2.3 respectively.

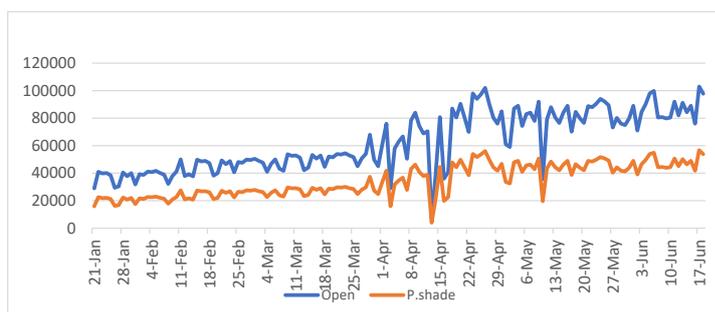
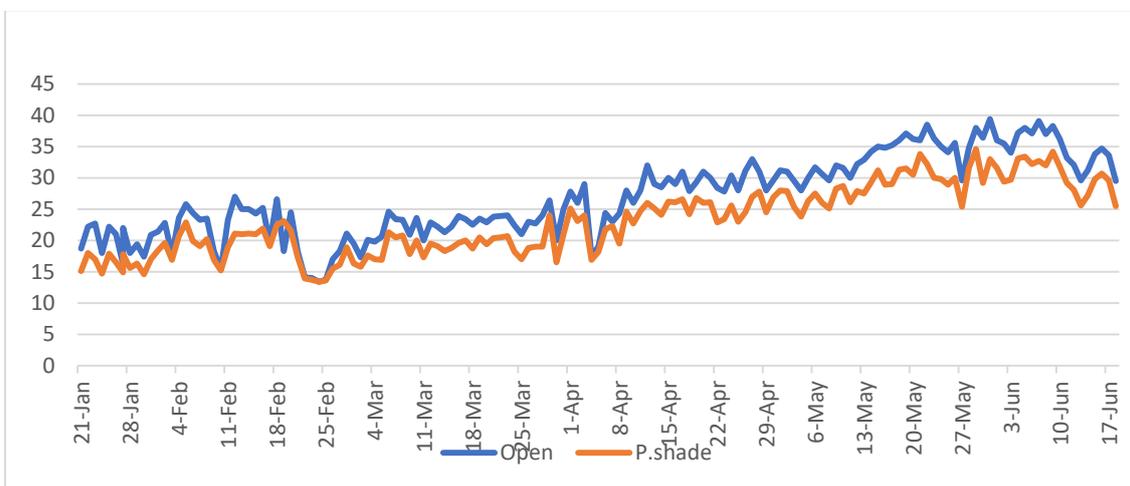
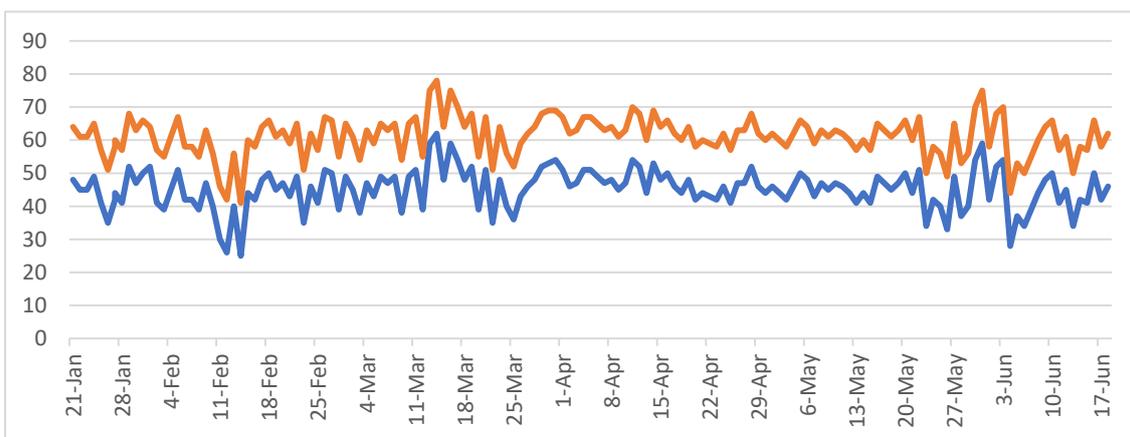


Figure: 1.1: Light Intensity (Lux) Measured Daily during the Experiment.



**Figure 2.1: Temperature (°C) Measured Daily during the Experiment.**



**Figure 3.1: Relative Humidity (%) Measured Daily during the Experiment.**

### Studied Parameters:

Data were recorded on Head diameter, Head height, Number of leaves plant<sup>1</sup>, Leaf area(leaf area was recorded with a leaf area meter (CI-201), Chlorophyll content(chlorophyll content was measured by SPAD meter (Konica Minolta Spad-502 plus) , Taste, Head fresh weight, Head dry weight(fresh and dry head weight was measured with a digital balance (Hytek Sf-400C), Days to flowers, Days to seed production, Plant height, Root length and Seed yield.

### Data Analysis

Collected Data from different parameters were subjected to the Analysis of Variance (ANOVA) technique [18]. The data were further subjected to the Least Significant Difference (LSD) test, to find out significant differences between individual means. Statistical software (Statistix 8.1) was used for computation.

### Results and Discussion

#### Head Diameter (cm)

The data regarding the head diameter of lettuce grown in different growing conditions on sowing dates are shown in Table 1. The ANOVA revealed that head diameter was significantly ( $P \leq 0.01$ ) influenced by growing condition and sowing date. The interaction between the growing condition and sowing dates was not significant. In growing condition the open field-grown plants produced the maximum head diameter (30.83 cm) while those sown in partial shade produced the smallest heads (26.88 cm). In sowing dates showed that maximum head diameter (32.54 cm) was noted in plants sown on 24<sup>th</sup> December closely followed by those planted on 8<sup>th</sup> January (31.55 cm) and 23<sup>rd</sup> January (30.50 cm). Minimum head diameter (24.65 cm) was observed from the plants sown on (9 March). There was a trend of head diameter gradually decreasing with the delay in sowing time.

Based upon the above data the open field-grown plants produced larger heads as compared to the partial shade-grown plants. It might be because the temperature and light intensity in the open field was optimum for lettuce growth which resulted in more food storage and chlorophyll content as compared to plants grown in partial shade where light intensity and temperature were low compared to open field during the growing period. Regarding efficient growth and yield, temperature and light intensity are the most important environmental factors that affect plant photosynthesis and water nutrient uptake [19]. In the present study, the difference in head diameter of plants grown in open and partial shade

might be due to the optimum temperature in the open field which resulted in an increase in head diameter compared to the partial shade. The present results are in accordance with those of Ruelland and Zachowski, (2010) who also mentioned that lettuce head diameter is greatly dependent on temperature and light intensity [19]. As the temperature increased, the diameter of the lettuce plants' heads decreased. Temperature is an important factor that influences plant growth and yield. High-temperature stress harms plant growth and production [20]. Temperatures of 15°C to 27°C are ideal for lettuce growth [21]. The maximum head diameter of early sown plants could be explained by the fact that the light intensity and temperature were more beneficial to lettuce productivity compared to the late sown plants. Our findings are in agreement with those of Singer *et al.*, (2015) who noticed that head height and head yield were affected when the plants were subjected to high light intensity and temperature because of late transplantation [22].

### Head Height (cm)

The data regarding lettuce head height grown in different growing conditions and sowing dates are presented in Table 1. The ANOVA revealed that the head height was significantly ( $P \leq 0.01$ ) influenced by growing conditions and sowing dates. The interaction between the growing conditions and sowing dates was not significant. In growing conditions revealed that the plants grown in partial shade produced maximum head height (25.63 cm) while those grown in the open field produced the minimum head height (22.01 cm). In sowing dates showed that maximum head height (26.22 cm) was noted in plants sown on 24<sup>th</sup> December, closely followed by those planted on 8<sup>th</sup> January (25.23 cm). Minimum head height (21.29 cm) was produced by plants sown on 9<sup>th</sup> March. There was a decreasing trend recorded in late sowings.

The lettuce plants grown in partial shade showed maximum head height. Plant growth is strongly influenced by environmental factors such as shading [23]. If the light intensity is too high, the plant may be subjected to high temperatures and drought stress [24]. These phytohormones cause the stems to lengthen, making the plants taller. The favorable partial shade condition may cause the plants to grow taller by increasing cell division and elongation, contributing to the increased head heights [25]. Our findings are following those of Rosli *et al.*, (2018), who reported that shade-grown plants grew taller than open-grown plants [26]. Yasoda *et al.*, (2018) also reported that the Cauliflower plant head height increased gradually during shading, which could be due to internode lengthening to capture more light.

Early-sown plants were recorded with maximum head height compared to those late-sown. It might be since early-sown plants received a better environmental condition than the late-planted plants, the earlier-grown plants had taller heads (24 Dec to 23 Jan) than the later plants (7 Feb to 9 March). There was a decreasing trend in lettuce plants' head height (cm), as the light intensity and temperature increased. In plants, high irradiance causes stomata to close, slowing photosynthesis and reducing growth [27]. Light intensity has an impact on plant morphology, photosynthesis, and secondary metabolism [28]. Due to the light intensity at early sowing, the decreased secondary metabolism in late-sown plants could explain why the plants had minimum head height. Temperature, too, has a significant impact on plant growth [20]. High temperatures affect the photosynthetic rate and plant development by causing damage to the chloroplast [29]. The above findings can be co-related with those of Grazia *et al.*, (2001) and Zervoudakis *et al.*, (2012) who reported that early sown plants were recorded with better growth because of optimal light intensities and temperatures in early sowing thus producing maximum head heights [30,31].

### Number of Leaves Plant<sup>-1</sup>

The data concerning lettuce leaves number plant<sup>-1</sup> grown in different growing conditions on different sowing dates is given in Table 1. The ANOVA revealed that the number of leaves was significantly ( $P \leq 0.01$ ) affected by growing conditions and sowing dates. The interaction between the growing condition and sowing dates was not significant. In growing conditions revealed that the plants grown in open produced the highest number of leaves plant<sup>-1</sup> (28.06) while those grown in partial shade produced the minimum number of leaves per plant (23.17). In sowing dates revealed that maximum number of leaves plant<sup>-1</sup> (28.30) were produced by plants sown on 24<sup>th</sup> December, closely followed by those planted on 8<sup>th</sup> January (28.16) and 23<sup>rd</sup> January (26.95) whereas, the plants sown on 9<sup>th</sup> March produced the minimum (20.76) number of leaves plant<sup>-1</sup>.

The open-grown lettuce produced maximum number of leaves compared to partial shade-grown plants. The growth of lettuce plants is influenced by the interaction of the environment and genotype [32]. The number of leaves is important because it indicates how much the cultivar is adapted to the growing condition [33]. Our results are in concurrence with the findings of Chen *et al.*, (2017) who stated that the number of leaves per plant of cotton plant decreased as the level of shading was increased and resultantly, adversely affected the opening of cotton bolls thus, the quality of fiber was reduced [34].

Lettuce plants that were sown earlier yielded more leaves than those sown late in the season. Because the temperature was optimum at the early sowing but higher at later planting dates, this decrease in the number of leaves could be due to high temperatures. As the temperature rises, most enzymatic reactions accelerate to their maximum speed, but after a certain point, activity begins to decline [35]. Plant metabolism is altered by high temperatures, which encourages a variety of bio-chemical and physiological changes in the plant that affect its growth and biological yield [36]. The current findings are also in agreement with Rakesh *et al.*, (2017), who found that plants cultivated on early dates produced more leaves than plants sown later [37]. Similar findings were reported by Kumar *et al.*, (2017), who found that basil

plants seeded early produced more leaves per plant than those sown later [38].

### **Chlorophyll Content (SPAD)**

The data regarding chlorophyll content (SPAD) of lettuce grown in different growing conditions on different sowing dates are shown in Table 1. The ANOVA showed that the chlorophyll content was significantly ( $P \leq 0.01$ ) influenced by the growing conditions and sowing dates. There was no significance between the growing conditions and sowing dates recorded. In growing conditions shown that the open field-grown plants had maximum chlorophyll content (24.29 SPAD), while those grown in partial shade had minimum chlorophyll content (20.74 SPAD). The sowing dates showed that maximum chlorophyll content (24.85 SPAD) was noted in the plant sown on 24<sup>th</sup> December closely followed by those sown on 8<sup>th</sup> January (23.49 SPAD). However, they also behaved like those sown on 23<sup>rd</sup> January and 7<sup>th</sup> February. Minimum chlorophyll content (20.56 SPAD) was recorded in plants sown on 9<sup>th</sup> March, which was also at par with those sown on 23<sup>rd</sup> January, 7<sup>th</sup>, and 22<sup>nd</sup> February). There was a trend of chlorophyll content gradually decreasing with the delay in sowing time.

Open field-grown plants were noted with maximum chlorophyll content compared to partial shade-grown plants because the temperature and light intensity were optimum in the open field for the growth of lettuce compared to those in partial shade during the growing period. For efficient growth and yield, temperature and light intensity are among the most important environmental factors. Shading not only decreases the total radiation needed for plant growth but also increases the fraction of diffused light, which is more efficiently used by plants [39,40]. Kosma *et al.*, (2013) reported that shade-grown plants had less chlorophyll content and less ascorbic acid level [23]. Our findings are in line with Wang *et al.*, (2003) who detected a decrease in chlorophyll content with the increase in shade levels in wheat plants [41].

In comparison to late-season, lettuce plants cultivated earlier produced higher leaf chlorophyll content, in our study. High temperatures damage the thylakoid membrane which resultantly affects photosynthesis and affecting plant growth [42]. Furthermore, high heat disturbs the activity of various enzymes involved in chlorophyll biosynthesis [43]. Our findings are in line with Sarwar *et al.*, (2013) who confirmed that the gladiolus plant grown early had the highest leaf chlorophyll content compared to those grown on delayed dates [44].

### **Leaf Area (cm<sup>2</sup>)**

The data concerning lettuce leaf Area (cm<sup>2</sup>) grown in different growing conditions and sowing dates are shown in Table 1. The ANOVA showed that the Leaf Area was significantly ( $P \leq 0.01$ ) influenced by growing conditions and sowing dates. The interaction between the growing conditions and sowing dates was not significant. In growing conditions indicate that open field-grown plants were noted with the maximum leaf area (810.75 cm<sup>2</sup>) while those grown in the partial shade were noted with the minimum leaf area (732.06 cm<sup>2</sup>). The sowing dates showed that maximum leaf area (792.08 cm<sup>2</sup>) was noted in plants sown on 24<sup>th</sup> December and 8<sup>th</sup> January (782.73 cm<sup>2</sup>). The minimum leaf area (754.80 cm<sup>2</sup>) was noted in plants sown on 9<sup>th</sup> March. However, it was also at par with the plants sown on 22<sup>nd</sup> February which resulted in (759.50 cm<sup>2</sup>) leaf area.

In comparison to plants grown in partial shade, open field-grown plants produced the most leaf area. This could be explained by the effect of increased temperature in the open field which hastened plant growth and reproduction. Additionally, the number of leaves in the open field was also more as compared to partial shade which is also the main reason for the lower leaf area in partial shade. Light intensity has a significant impact on subsequent photosynthetic activity [21]. Photosynthesis rate and overall plant growth become reduced when plants are subjected to low light intensities [45,46]. Chang *et al.*, (2008), also reported that the increasing level of shade had significantly reduced the photosynthesis rate, resulting in a reduction in leaf area [21]. Shade also reduces lettuce leaf thickness as reported by Nam, (1996) that the fresh mass of lettuce was decreased when lettuce was subjected to shade [47]. According to Lee *et al.*, (2008), environmental factors influenced the thickness and volume of Chinese cabbage leaves.

Concerning the sowing dates the early grown plants were having greater leaf area compared to the plants grown on later dates because at later sowing dates the light intensity and temperature were high compared to early growing dates. Due to higher temperature and light intensity, the plant cells are damaged consequently the rate of photosynthesis reduces [48]. It causes cellular disruption and harms the physiological functions of a plant when exposed to higher temperatures and light intensities [49]. Abdumanobovich *et al.*, (2020) also testified that early-sown plants had maximum leaf areas than the late-sown ones [50]. Hocking and Stapper, (2001) reported that growing wheat and canola late in the season reduced leaf area and vegetative growth, particularly the number of lateral branches in canola and tillers in wheat, resulting in lower grain yields [51]. According to them a decrease in the number of pods per plant due to fewer lateral branches and pods per branch is the main cause of lower yields in late-sown oilseed rape.

### **Taste**

The data concerning lettuce taste grown in different growing conditions and sowing dates are shown in Table 2. The ANOVA showed that the lettuce taste was significantly ( $P \leq 0.01$ ) influenced by growing conditions and sowing dates. The interaction between the growing conditions and sowing dates was not significant. In growing conditions indicate that partial shade-grown plants were sweeter (8.04) than those grown in the open field (5.06). The means regarding the sowing dates showed that lettuce plants sown on 24<sup>th</sup> December were sweeter (8.34) closely followed by 8<sup>th</sup> sowing

plantations (7.62). The plants sown on 9<sup>th</sup> March were recorded with having (4.97) points regarding the taste. However, it was also at par with the plants sown on 22<sup>nd</sup> February which resulted in (5.61) points.

The plants grown in the partial shade were noted with a sweeter taste than those grown in the open field. This might be due to the fact, that the temperature and light intensity were optimum and lower in partial shade as compared to open field. The lettuce plants require cool to slightly warmer temperatures for their growth, production, and taste. Temperature above 27°C causes lettuce to bolt and results in bitterness, loose fluffy heads, and tip burn [8]. Our results are consistent with those of Zao and Carey (2009), who reported that shade-grown plants were sweeter than those grown in open during high temperatures [52]. Ilić *et al.*, (2017) also reported that butter head lettuce in shade had enhanced the chlorophyll a, chlorophyll b, and carotenoid contents compared with unshaded lettuce as a result shaded lettuce were sweeter than those grown in the open field [53].

Regarding the sowing dates, lettuce plants sown earlier were sweeter than those sown late. Due to unfavorable high temperatures, lettuce production was constrained during the summer months, increasing the probability of leaf bitterness [54]. Lettuce yield and quality decline as planting dates approach warmer temperatures and longer days [55]. Bitter flavors can develop quickly in these conditions, and the leaves become less delicate [56]. Our results are advocated by who reported that lettuce cultivated at very high ambient temperatures has a bitter flavor that makes it unmarketable [57].

### Head Fresh Weight (g)

The data concerning head fresh weight (g) of lettuce grown in different growing conditions on different sowing dates is given in Table 2. The ANOVA revealed that the head fresh weight was significantly ( $P \leq 0.01$ ) influenced by growing conditions and sowing dates. The interaction between the growing conditions and sowing dates was not significant. In growing conditions showed that the lettuce open-grown plants produced the massive head fresh weight (189.93 g) while those grown in partial shade produced the minimum head fresh weight (152.50 g). The sowing dates showed that maximum head fresh weight (186.78 g) was noted in plants sown on 24<sup>th</sup> December whereas, the minimum head fresh weight was noted in plants sown on 22<sup>nd</sup> February (162.33 g) and those planted on 9<sup>th</sup> March (157.89 g). However, it was also at par with the plants sown on (162.33 g) of head fresh weight. There was a decreasing trend in head fresh masses of lettuce as the sowing date was delayed.

In comparison to plants grown in partial shade, those grown in the open field produced the maximum head fresh weight. This could be because temperature hastened the stem elongation. Additionally, light has a significant impact on photosynthesis [58]. Shade causes a reduced photosynthetic activity which as a result causes the plants to have a decreased ratio of leaf area and consequently, the fresh biological yield of the plants gets influenced and reduces [21]. The present results are in line with those of Le *et al.*, (2008), who stated that the environment in which plants were grown had influenced the leaf heaviness and volume of Chinese cabbage and thus produced light head weight cabbages. Our findings are also in concurrence with those of Kumar *et al.*, (2014) who find-out that under open conditions, the fresh biomass of leaves, stems, and flowers were significantly higher in marigold plants [38]. They also reported that stems contributed more to total plant biomass than leaves in plants under all shade treatments.

The head fresh weight of early-sown lettuce plants was higher than that of late-sown lettuce plants. The increase in fresh weight of early grown lettuce may be related to the optimum temperature and light intensities were ideal and favourable for its development compared to late sown lettuce but when the temperature and light intensities were increased due to late sowing the plants were easily gone to bolting which adversely impacted the overall head fresh weight of the plants. The high temperatures affect stomata conductance, causing stomata to close and the photosynthetic rate to slow [59]. Agreeing with our results Birojaneka *et al.*, (2020), observed that basil plants cultivated on prior dates produced maximal leaf fresh weight compared to later sowing dates [60]. Choi *et al.*, (2004) also testified that high temperatures induced decreased head fresh weight and resultantly, the head dry weight was also decreased [61].

### Head Dry Weight (g)

The data regarding lettuce head dry weight (g) grown in different growing conditions and sowing dates are presented in Table 2. The ANOVA showed that the head dry weight was significantly ( $P \leq 0.01$ ) influenced by growing conditions and sowing dates. There was no significance recorded between the interaction of growing conditions and sowing dates. In growing conditions revealed that the plants grown in open produced the maximum head dry weight (12.93 g) while those grown in partial shade produced the minimum head dry weight (10.30 g). In sowing dates revealed that maximum head dry weight (12.43 g) was noted in plants sown on 24<sup>th</sup> December closely followed by those planted on 8<sup>th</sup> January (12.12 g). Minimum head dry weight (10.77 g) was noted in plants sown on 9<sup>th</sup> March. However, it was also at par with the plants sown on 22<sup>nd</sup> February which resulted in (10.16 g) head dry weight.

Concerning the growing condition open field-grown plants had produced the highest head dry weight than partial shade-grown plants. This happened because in open the plants got the optimum light and temperature which has a significant impact on the biological yield of a plant. Low light in shade reduces the leaf area and consequently decrease in dry weight occurs [62]. In our case the results can be correlated with Liu *et al.*, (2003) that shade reduced the dry weight of root and stem tissues when studying the impact of three shading levels on pot-grown tomatoes.

The head dry weight of lettuce plants grown early in the season was higher than that of plants grown later in the season. Because at the early sowing, lettuce plants got the optimum light intensity and temperature but the vegetative growth ceased in later sowing dates, the decrease in the dry weight of leaves in late sowing dates could be due to high temperatures and light intensity which induces the lettuce to shift from vegetative growth to reproductive stage which resultantly, influenced the overall biological yield [35]. High temperatures harm winter plant development [20]. The above results are similar to those of Sebthamadi *et al.*, (2013), who found that early sown plants were noted with greater dry weight than those sown late. Our findings are also consistent with those of Galieni *et al.*, (2016), who found that low light intensity caused by artificial shade reduced the number of leaves per plant, and thus a decrease in leaf dry biomass was noted [63].

### Days to Flowering

The data concerning days to flower initiation of lettuce grown in different growing conditions and sowing dates are shown in Table 2. The ANOVA showed that the days to flower initiation were significantly ( $P \leq 0.01$ ) influenced by growing conditions and sowing dates. The interaction between the growing condition and sowing dates was not-significant. In growing conditions days to flowering showed that the plants grown in open took minimum days to flowering (84.91) while those grown in partial shade took maximum days to flowering (99.08). In sowing dates showed that a greater number of days to flowering (95.49) were taken by the plants sown on 24<sup>th</sup> December closely followed by those sown on 8<sup>th</sup> January (93.31). However, the minimum days to flowering (70.77) were taken by plants sown on 9<sup>th</sup> March. There was a trend of decreasing days to flowering with the delay in sowing dates.

In comparison to lettuce plants grown in partial shade, open field-grown plants took fewer days to flowering. In growing conditions, this difference happened because of an increase in daily temperature, light intensity, and a decrease in humidity. Flowering in lettuce is influenced by environmental factors, particularly temperature [64]. Stem elongation or the formation of flower stalks in plants is usually aided by high temperatures and light intensity [8]. In lettuce, stem elongation, also known as bolting, occurs when the temperature increases [55]. Our findings corroborate those of Ilic and Fallik, (2017), who found that flowering was delayed in Summer Pastels when grown at a low light intensity and daily temperature [58].

According to the above findings, early-sown lettuce plants had taken more days to flowering than those sown later in the season. This difference in flowering time could be due to the early season's optimal temperature, humidity, and light intensity compared to late-season plants in which high temperature, light intensity, and humidity were recorded. Additionally, the impact of increased temperature in the open field which hastened plant growth and reproduction can also be the cause of minimum days to flowering in plants sown late. The environmental temperature and light intensity are the two main factors that play an important role in plant physiological functions such as photosynthesis and plant developmental stages [65]. The above findings corroborate with Sadeghi *et al.*, (2009), who revealed that early cultivated plants took more days to flowering than plants cultivated at later sowing dates in the season [65]. Agreeing with our results, Gresta *et al.*, (2008) also reported that early sowing time has increased the quantitative and qualitative characteristics of saffron, such that early flowering and larger combs were recorded in early sown saffron [66].

### Days to Seed Production

The data concerning days to seed production of lettuce grown in different growing conditions and sowing dates are shown in Table 2. The ANOVA showed that days to seed production were significantly ( $P \leq 0.01$ ) influenced by growing conditions and sowing dates. There was no significance between the growing conditions and sowing dates. In growing conditions revealed that the partial shade-grown plants took maximum days to seed production (116.30) while open field-grown plants took fewer days to seed production (98.91). The sowing dates revealed that maximum days to seed production were taken by plants sown on 24<sup>th</sup> December (118.17) and 8<sup>th</sup> January (115.17) closely followed by plants sown on 23<sup>rd</sup> January (110.67). The minimum days to seed production (93.27) were recorded by plants sown on 9<sup>th</sup> March. There was a decreasing trend recorded though out the growing season.

The partial shade-grown lettuce took greater days to seed production compared to open field-grown plants. This difference between the growing conditions was because lettuce plants were subjected to high temperature and light intensity in the open field while the plants in the partial shade were comparatively less subjected to the harsh environmental conditions. The growing conditions especially the environmental part critically influenced the flowering and seed production [64]. The lettuce seeds take 12 to 21 days to reach maturity. However, the maturity time is critically dependent on the environmental conditions [64]. The present results are in concurrence with Dufault *et al.*, (2006), who revealed that lettuce seeds reach to maturity in 11 days when the mean daily temperature was 20-30°C whereas, it took 13 days when grown at the temperature range of 15-20 [55].

Lettuce plants that were planted early in the season took maximum days to produce seeds than those planted later in the season. The humidity in the plant's environment also influences physiological functions like stomatal conductance and transpiration [67]. The sowing in the early season had a significant impact on lettuce growth, yield, and yield components such as plant height, days to seed production, days to flowering, and the number of seeds whereas growth was decreased as planting was postponed. Our results are in correspondence with those of Ahammad *et al.*, (2009), who stated that the planting time had a noteworthy impact on tomato growth and yield components [68]. Tomato plant

height, days to fruit set, fruit number, fruit weight, and yield components all decreased, as planting was postponed.

### **Plant Height (cm)**

The data regarding lettuce plant height grown in different growing conditions and sowing dates are shown in Table 3. The ANOVA revealed that plant height was significantly ( $P \leq 0.01$ ) influenced by growing conditions and sowing dates. There was no significance between the growing condition and sowing dates. In growing conditions revealed that the plants grown in the partial shade were recorded with maximum plant height (91.93 cm) while the plants grown in open were noted with minimum plant height (78.39 cm). The sowing dates showed that the maximum plant height (94.55 cm) was noted in plants sown on 24<sup>th</sup> December followed by those plants sown on 8<sup>th</sup> January (90.20). The minimum plant height (76.15 cm) was recorded by plants grown on 9<sup>th</sup> March which was also at par with plants sown on 22<sup>nd</sup> February. There was a trend of plant height gradually decreasing with the delay in sowing time.

The lettuce plants grown in partial shade showed maximum plant height compared to those grown in the open field. This might be because in the partial shade there was low light intensity compared to the open field. If the light intensity is too high, the plant may be subjected to high temperatures and drought stress [24]. The favorable partial shade condition may cause the plants to grow taller by increasing cell division and elongation, contributing to the increased plant heights [25]. Plant growth is strongly influenced by environmental factors such as shading, as reported by Kosma *et al.*, (2013) [23]. The above results are in concurrence with those of Rosli *et al.*, (2018) who testified that plants shade-grown plants grew taller than those grown in the sun [26]. An increase in plant height due to a low R/FR ratio is reported by Kosma *et al.*, (2013) in bean plants [23]. The same results were also obtained by Franklin and Whitelam, (2005) in *Pisum sativum* and *Brassica napus* [69].

With increased light intensity and temperature, the height of the lettuce plants decreased that is the reason that the plants sown earlier were less influenced by the harsh temperature and light intensity compared to those sown late. The plants grown earlier were taller than plants grown on delayed sowing dates because the plants were more prone to bolting at late sowing dates, which consequently decreased their overall height. The current findings are similar to those of Zervudakis *et al.*, (2012), who testified that common sage plants grew taller grown when grown in low light intensities and temperatures than those in high temperature and intensity [31]. *Chrysanthemum* plants also showed an increase in plant height when grown in low solar radiations [70].

### **Number of Seeds Plant<sup>-1</sup>**

The data regarding the number of seeds plant<sup>-1</sup> of lettuce grown in different growing conditions on different sowing dates is presented in Table 3. The ANOVA revealed the number of seeds plant<sup>-1</sup> was significantly ( $P \leq 0.01$ ) influenced by growing conditions and sowing dates. There was no significant impact between the growing condition and sowing dates. The growing conditions revealed that the plants grown in open produced the more number of seeds plant<sup>-1</sup> (11428) whereas, the partial shade-grown plants produced the minimum No. of seeds plant<sup>-1</sup> (8614). In sowing dates revealed that the maximum number of seeds plant<sup>-1</sup> (10433) was given by plants sown on 24<sup>th</sup> December closely followed by those sown on 8<sup>th</sup> January (10285) and 23<sup>rd</sup> January (10199). The minimum numbers of seeds plant<sup>-1</sup> (9642) were produced by plants sown on 9<sup>th</sup> March. However, it was also at equivalence with the plants sown on 7<sup>th</sup> February and 22<sup>nd</sup> February.

Open field-grown plants produced more seeds plant<sup>-1</sup> than those sown in partial shade, which may perhaps be the higher temperature and light intensity in the open field. The formation of the seed in the lettuce crop is accelerated by higher temperatures [41]. The above results are in correspondence with those of Himbindu *et al.*, (2017) who testified that low light seriously decreased the seed yield of sunflower crop. The same results were also obtained by Jumrani *et al.*, (2020), who reported that seed yield was significantly influenced when the shading level was increased in soybean production [71].

When sowing dates, the early-sown lettuce plants yielded the most seeds compared to late-sown lettuce plants. The earlier sowing at optimal temperature, as opposed to the late sowing could explain the increase in seeds in early-season plants. Serafin *et al.*, (2021) also found that soybean plants cultivated early in the season yielded more seeds than those cultivated later in the season. Arshad *et al.*, (2007) also testified that cotton sown early produced 10% more flowers and 23% more opened bolls which resulted in 18% more seeds than late grown cotton which is in agreement with our findings [72].

### **Seed Yield (Kg ha<sup>-1</sup>)**

Data concerning the seed yield (kg ha<sup>-1</sup>) of lettuce are in Table 3. The ANOVA shows that seed yield was significantly ( $P \leq 0.01$ ) influenced by the growing conditions and sowing dates. The interaction between growing conditions and sowing dates was not significant. The growing conditions showed that open field-grown plants produced more seed yield (1042.8 kg ha<sup>-1</sup>), while those grown in the partial shade produced less seed yield (757.8 kg ha<sup>-1</sup>). The sowing dates revealed that maximum seed yield was obtained by plants grown on 24<sup>th</sup> December (931.1 kg ha<sup>-1</sup>) and 8<sup>th</sup> January (923.8 kg ha<sup>-1</sup>) plantations. The minimum seed yield (865.1 kg ha<sup>-1</sup>) was produced by plants grown on 9<sup>th</sup> March. There was a decreasing trend in seed yield when the sowing time was delayed.

Concerning the growing condition open field-grown lettuce produced the highest seed yield than those grown in partial shade, this difference could be due to the higher temperature and light intensity in the open field. However, rising temperatures and light intensities harm lettuce vegetative growth, resulting in stunted and sluggish reproductive growth. The above results are in concurrence with Welbum (2005) who testified that low light had seriously decreased the seed yield of sunflower when compared to open field production [64]. The same results were also obtained by Jumrani *et al.*, (2020), who reported that seed yield was significantly affected when the shade level was increased in soybean production [71].

The seed yield of lettuce plants cultivated early in the season was higher compared to late sown in the current study. In comparison to the late sowing season, the high seed yield of lettuce plants in the early season may be related to optimum temperature and light intensity during the research duration. Light intensity and temperature increased during late sowing time, according to environmental data. Beyond a certain limit, higher air temperatures have a deleterious impact on plant growth, pollination, and reproductive stages of a plant [73]. High temperatures throughout the productive period affect fertilization, and grain development, all of which have an impact on the crop's yield [74]. Our results are supported by Arshad *et al.*, (2007), who testified that cotton crops sown early produced 10% more flowers and 23% more opened bolls which resulted in 18% more seeds than late-grown cotton [72]. Our findings are also comparable to those of Rakesh *et al.*, (2017), who found that early cultivated basil plants yielded more seeds than basil sown later [37].

### Root Length Plant<sup>-1</sup> (cm)

The data regarding root length of lettuce grown in different growing conditions on different sowing dates is shown in Table 3. The ANOVA showed that the root length was significantly ( $P \leq 0.01$ ) influenced by growing conditions and sowing dates. The interaction between the growing condition and sowing dates was not significant. In growing conditions revealed that the plants grown in the open field produced maximum root length (29.07 cm) while those grown in the partial shade produced minimum root length (22.78 cm). In sowing dates showed that maximum root length (28.06 cm) was noted on 24<sup>th</sup> Dec followed by 8<sup>th</sup> January (26.73 cm) and 23<sup>rd</sup> January plantations (26.27 cm). Minimum root length (24.17 cm) was recorded by plants sown on 9<sup>th</sup> March. However, it was at par with plants sown on the 23<sup>rd</sup> and 7<sup>th</sup> February sowing dates.

The open field-grown lettuce was noted with maximum root length compared to those grown in partial shade. Root growth influenced by light was less, compared to shoot growth. Low temperature reduces the number of lateral roots and reduces root surface area, resulting in decreased root water uptake and also reported that shading reduced the root length. Our results are in agreement with those of Rosli *et al.*, (2018) who recorded that shading influenced the overall growth of turf grasses [26]. They reported that the turf grasses which were grown under shade were having minimum root ratio.

Lettuce plants sown before 23<sup>rd</sup> January were recorded with maximum root length compared to those sown after 23<sup>rd</sup> January. This difference was there because of the increased light intensity and temperature. The ratio of root length is greatly dependent on the environmental temperature, humidity, and light intensity. Our results can be comparable with the findings of Kakaraparthi *et al.*, (2013) also reported that sowing dates had significantly influenced the root length and root yield while studying the impact of sowing dates on *Withania somnifera*, a common medicinal root plant [75]. They reported that maximum root length was recorded in earlier sowing compared to late sown plants.

### Conclusions:

The growing conditions and sowing dates significantly affected the growth and yield of lettuce. The open field-grown lettuce showed maximum chlorophyll content, the number of leaves plant<sup>-1</sup>, head fresh mass, head dry mass, leaf area, seed yield, root length, and the number of seeds plant<sup>-1</sup> whereas partial shade-grown plants took more days to flowering, seed production, and produced the tallest plants with the good taste. The plants sown on 24<sup>th</sup> December exhibited maximum chlorophyll content, head diameter, head height, head fresh mass, head dry mass, days to flowering, days to seed production, number of seeds plant<sup>-1</sup>, seed yield, taste, plant height, and root length.

Treatment	Attributes				
	Head Diameter	Head Height	No. of Leaves	Chlorophyll content	Leaf Area
Open Field	30.83A	22.01B	28.06A	24.29A	810.75A
Partial Shade	26.88B	25.63A	23.17B	20.74B	732.06B
LSD ( $P \leq 1\%$ )	1.4	1.6	4.8	2.7	2.2
Sowing Dates					
24 December	32.54 A	26.22 A	28.30 A	24.85 A	792.08 A
8 January	31.55 A	25.23 AB	28.16 A	23.49 A	782.73 A
23 January	30.50 A	24.65 BC	26.95 A	22.74 AB	772.38 B

7 February	27.83 B	23.24 CD	26.18 AB	22.66 AB	766.92 BC
22 February	26.06 BC	22.24 DE	23.35 BC	20.80 B	759.50 CD
9 March	24.65 C	21.29 E	20.76 C	20.56 B	754.80 D
LSD (P ≤ 1%)	2.2	1.5	2.9	2.2	3.5
Interactions Growing conditions × Sowing dates	NS	NS	NS	NS	NS

**Table 1: Influence of Different Growing Conditions and Sowing Dates on lettuce Head Diameter, Head Height, No. of Leaves, Chlorophyll Content, Leaf Area**

Treatment	Attributes				
Growing Conditions	Taste	Head Fresh weight	Head Dry weight	Days to Flowering	Days to Seed Production
Open Field	5.06B	189.93A	12.83A	78.39B	98.91B
Partial Shade	8.04A	152.50B	10.12B	92.25A	116.30A
LSD (P ≤ 1%)	0.1	1.5	0.1	0.6	0.9
Sowing Dates					
24 December	8.34 A	186.78 A	12.42 A	95.49 A	118.17 A
8 January	7.62 AB	181.06 B	12.12 AB	93.31 AB	115.17 A
23 January	6.84 BC	171.00 C	11.40 BC	88.17 BC	110.67 AB
7 February	5.91 CD	168.33 C	10.73 CD	84.48 CD	106.17 BC
22 February	5.61 D	162.33 D	10.16 DE	79.70 D	102.21 C
9 March	4.97 D	157.78 D	9.79 E	70.77 E	93.27 D
LSD (P ≤ 1%)	0.3	1.6	0.2	2.7	2.5
Interactions Growing conditions × Sowing dates	NS	NS	NS	NS	NS

**Table 2: Influence of Different Growing Conditions and Sowing Dates on Taste, Head Fresh Weight, Head Dry Weight, Days to Flowering, Days to Seed Production**

Treatment	Attributes			
Growing Conditions	Plant Height	No. of Seed Plant <sup>1</sup>	Seed Yield kg ha <sup>-1</sup>	Root Length
Open Field	78.38B	11428A	1042.8A	29.07A
Partial Shade	91.93A	8614B	757.7B	22.78B
LSD (P ≤ 1%)	6.9	0.7	10.2	0.3
Sowing Dates				
24 December	94.55 A	10433 A	931.1 A	28.06 A
8 January	90.20 AB	10285 A	923.8 A	26.73 AB
23 January	86.67 BC	10199 A	910.8 B	26.27 ABC
7 February	83.28 CD	9871 B	892.9 C	25.08 BC
22 February	80.10 DE	9695 B	878.2 D	24.79 BC
9 March	76.15 E	9642 B	865.1 E	24.17 C
LSD (P ≤ 1%)	5.4	3.8	107.4	0.8
Interactions Growing conditions × Sowing dates	NS	NS	NS	NS

**Table 3: Influence of Different Growing Conditions and Sowing Dates on Plant Height, No. of Seed Plant, Seed Yield, Root Length.**

## Conflict of Interest Statement

The author(s) declare(s) that there is no conflict of interest.

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