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Review Article

Physio-morphic Traits as Influenced by Seasonal Variation in Sunflower: A Review

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ABSTRACT

Owing to its wide adaptability, sunflower can be planted twice a year in spring and autumn. Nonetheless crop performance is strongly influenced by this seasonal variation. In this regard, morphological and physiological performance of spring sown sunflower is slower during early season than that sown in the autumn. Nonetheless progressive increase has been witnessed in physio-morphic functions like allometry and assimilation rate with the progressive rise in temperature during spring, however any increase in temperature, after the critical limit, may result in substantial decline in physio-morphic expressions. Any decrease in temperature later in the season may suppress the performance of autumn sown sunflower. Agronomic and yield traits such as, plant height, achenes number per head and achenes weight are also influenced by temperature and growth duration and finally affect the crop yield. Decrease in ambient temperature markedly influences the physio-morphic expressions of sunflower during both vegetative and reproductive growth phases. Seasonal variability in sunflower performance regarding physio-morphic traits indicated better capture and utilization of environment-driven resource (temperature, light, photoperiod & soil water) during spring compared to autumn sowing in the sub humid conditions of Pothwar. Usually there is a linear relationship amongst growing degree days, yield and yield related traits during both spring and autumn seasons. Here we discuss the influence of environmental variation on morphological and physiological characteristics in sunflower.

Key Words: Seasonal changes; Temperature; Physio-morphic attributes; Spring; Autumn; Sunflower

INTRODUCTION

Sunflower performs relatively well in warm season but is sensitive to low temperatures (Brouder *et al*., 2008). Pakistan is bestowed with various ecologies, where oilseed crops fit well. Owing to its wide range of adaptability, here sunflower can be cultivated twice a year during spring and autumn.

Sunflower performs better in longer growing season with high temperatures (Johnston *et al.*, 2002). As temperature is high with better radiation interception, plant growth, development, physiological processes and oil yield is usually higher during summer than winter season (Rawson *et al.*, 1984). Progressive decrease in achenes per head was observed in cultivars planted in autumn than these planted in spring (Nazir *et al.*, 1986).

Seasonal changes generate differences in gas exchange rates as variation in climatic factors affect these attributes in variable ways (Baydar & Erbas, 2005). Many physiological processes are sensitive to low temperature affecting plant functioning and yield attributes. Relatively low temperature prevails during most of the season for autumn planted crops, resulting in an imbalance between source of energy and metabolic sink. Better growth and productivity during spring season is commonly observed due to the influence of environmental variables (Baydar & Erbas, 2005).

Photosynthetic rate is the maximum at intermediate temperature and it is reduced both due to increase or decrease in ambient temperatures (Hikosaka *et al*., 2006). However gradual rise in temperature caused an increase in physiological metabolism up to maximum temperature and further increase in temperature showed reverse effect (Wang *et al*., 2008).

Plant growth, development and productivity are affected by various biotic and abiotic factors (Jaleel *et al*., 2009; Farooq *et al.*, 2009a, b). Accumulation of plant dry matter is the result of net CO_2 exchange rate between a crop and environment. Measurement of net CO_2 exchange rates vary in hot and cool temperatures thus affects physiological processes associated with plant growth and productivity (Bugbee & Monje, 1992). Prevailing growing stress conditions adversely affect crop growth and yield attributes (Jaleel *et al*., 2008). Growth rate of plants at warmer micro sites was 34-63% higher than that at cooler micro site and leaves at warmer micro site got higher irradiance exposure, gained 10% greater net carbon compared to leaves at cooler micro site (Ali *et al.*, 1994).

The final sunflower productivity is determined

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primarily by net assimilation rate, leaf area and crop growth duration. More the leaf area and crop growth duration, higher will be the assimilation rate contributing towards yield, which is obvious in spring sowing characterized by long growth period (Reddy *et al.*, 2003). Seasons with high temperatures and low humidity at pollination affects pollination thus producing achenes of low weight, empty and sterile, causing low yield (Bayda & Erbas, 2005). Longer reproductive phase and warmer temperature at the time of seed development (spring sown) of the crop are favorable for high oil contents and yield (Weiss, 2000).

Any change in the ambient environment triggers the change in the pattern of transpiration and photosynthesis. Here primary driver governing the crop growth rate is temperature (Baydar & Erbas, 2005) and any decrease in ambient temperature results in assimilation rate and its utilization (Paul *et al.,* 1990). Decline in ambient temperature accompanied with precipitation during fall results in reduced assimilate translocation and thus final crop yield (Kaleem *et al.,* 2009).

Here we have reviewed the influence of seasonal change on the morphology, allometry, physiology and yield of sunflower.

Seasonal Variation and Morphological Attributes

Phenology: Environmental variation has strong influence on the crop phenology in addition to other traits in sunflower. Plant phenology is dependent upon environmental factors (Pillai *et al*., 1995). Specific adaptability of genotypes explains the phenomenon of a genotype performing well in an environment but not in other environments (Fahr, 1987). Higher temperature not only promotes but also hastens germination (Khalifa *et al*., 2000). In most of the crop species, vegetative growth and floral initiation is accelerated by high temperature. An increase in daily average temperature from 15 to 27°C shortened the period from emergence to floral initiation phase in sunflower from 23 to 19 days after sowing (DAS, difference of 21%) at high radiation and from 33 to 23 DAS (difference of 32%) at low radiation (Connor & Sadras, 1992). Floral initiation occurred more quickly at 15 h photoperiod than at 11 h, establishing a long day response. Longer photoperiod (16 h) accelerated the plant development such as seed germination, initiation and growth pattern of leaves and floral bud induction (Connor & Sadras, 1992). In this regard sunshine hours from flowering to ripening are the most important factors influencing seed oil contents (Wang *et al*., 1997). Temperature and photoperiod are thus the major environmental attributes affecting sunflower phenology (Seiler, 1983).

Allometry: Temperature is an important climatic attribute affecting leaf emergence, leaf area and plant height (Kaleem *et al.,* 2009). Any change in ambient climate strongly influences the morphological and quantitative variables including plant height, head diameter, achene number per head, achene weight and oil contents in sunflower (Killi *et al*., 2005).

Table I: GDD, yield and yield components of sunflower hybrids during autumn

Hybrids	GDD	H.D (cm)	AH^{-1}	HSW(g)	yield (kg ha^{-1})
(A) AUTUMN 2003					
Super-25	1469.0e	14.9 bc	442.7 b	5.3 a	1597.0 bc
Parsun-1	1514.0d	14.4 cd	464.0 b	4.3 c	1390.0 d
SMH-9706	1561.0c	13.8 d	501.8 b	4.8 b	1514.0 cd
Award	1578.0b	15.3 b	564.6 a	5.5 a	1689.0 ab
Hysun-33	1598.0a	16.0 a	579.0 a	5.5 a	1760.0 a
SE	4.38	0.22	19.97	0.14	45.50
(B) SPRING 2004					
Hybrids	**GDD**	**H.D (cm)**	**AH^{-1}**	**HSW(g)**	**yield (kg ha^{-1})**
Super-25	1656.0c	14.06 b	602.10 c	8.03 bc	2024.0 b
Parsun-1	1800.0b	13.94 c	672.00 b	7.60 c	2172.0 b
SMH-9706	1782.0b	13.64 c	709.80 b	7.55 c	1985.0 b
Award bc	1890.0a	15.10 a	659.10	8.29 ab	2150.0 b
Hysun-33	1900.0a	14. 18 b	781.00 a	8.61 a	2832.0 a
SE	11.24	0.29	22.79	0.17	106.36

Abbreviations: GDD (growing degree days), HD (head diameter), AH^{-1} (achene per head), HSW (hundred seed weight)
(Source: Qadir *et al*., 2007)

Table II: Effects of growth durations on evaluated traits of groundnut

Growth duration	HSW		BIO		HI		PY	
	2001	2002	2001	2002	2001	2002	2001	2002
120 days	68.4	74.8	8.4	9.5	37.2	35.6	3.4	3.6
140 days	85.0	89.2	9.1	10.4	40.7	38.6	3.9	4.2
160 day	92.5	98.3	9.7	11.0	40.8	40.2	4.2	4.7
LSD (5%)	0.6	0.7	0.1	0.1	0.5	0.5	0.1	0.1

Abbreviations: HSW= 100-seed weight (g); BIO= Biomass (t ha^{-1}); HI= Harvest index (%); PY= Pod yield (t ha^{-1})
(Source: Caliskan *et al*., 2008)

Table III: Effect of seasonal variations on growth and development of sunflower

Hybrids	Plant height (cm)		Dry matter (g m^{-2})		Yield (kg ha^{-1})	
	spring	autumn	spring	autumn	spring	autumn
Parsun 1	136.61 b	110.53 b	2953.2 a	1491.93 a	1757 b	1628 b
SMH-9706	148.21 ab	123.90 a	3183.6 a	1435.7 a	2122 a	1631 b
SMH-9707	137.63 b	108.84 b	3223.03 a	1467.38 a	1738 b	1353 c
Suncross-42	156.73 a	126.83 a	3355.86 a	1600.63 a	2175 a	1827 a
XF-263	86.41 c	72.98 c	1182.0 b	787.5 b	940 c	768 d

Means sharing a common letter are non significant at 5 % level of probability
(Source: Hassan *et al*., 2005)

Stress during the crop growth strongly restricts the leaf growth and development of optimal leaves, which is important for photosynthesis and dry matter yield and the extent of restriction depends on the severity of stress (Farooq *et al*., 2009a). Under stress conditions, plant productivity is strongly dependent on the dry matter partitioning and temporal biomass distribution (Jaleel *et al*., 2008). Plants grown at two different environments showed differences in shoot growth rate (Hendrickson *et al.,* 2004).

Low temperature stress prevailed during autumn not only influenced morphological attributes resulting in reduction in number of leaves per plant and small leaf area (Fig. 1) but also induced decrease in physiological attributes such as chlorophyll content, photosynthetic rate and stomatal conductance (Figs. 2 & 4). Crop development was slower during the spring season at start, as after emergence temperature was lower than in autumn sowing, thus crop growth duration was longer (Kaleem *et al.,* 2009), which intercepted more solar radiation and accumulated more photosynthates, producing more dry matter than in autumn sowing (Feburriera & Abreu, 2001). A linear increase in number of leaves per plant with the accumulation of temperature was observed as number of leaves was the maximum at the highest temperature (Goyne *et al*., 1989). The hybrids, which remained for longer duration in the field produced higher yield and yield components due to accumulation of more growing degree days (GDD) than other hybrids, which remained for shorter period of time accumulating lesser GDD (Table I; Qadir *et al*., 2007). Similarly, seed yield and all other crop traits significantly increased with lengthening of growth duration in both years of experimentation (Caliskan *et al*., 2008; Table II).

There was an increase in leaf area duration, number of leaves, leaf area index and crop growth duration in spring sown sunflower (Jose *et al*., 2004). Plants grown under conditions of long photoperiod produced more leaves than those grown under short photoperiods (Linnerman *et al*., 1994). Accordingly there was significant linear relationship between temperature and stem weight and biomass, whereas stem weight increased with temperature (28°C) nonetheless further increase in temperature (32°C) caused a little reduction in biomass (Dennis *et al.*, 2006). While in another study, it was observed that spring sown sunflower matured in 112 days, while autumn sown sunflower matured in 85 days (Hassan *et al*., 2005). Here increase in temperature during early autumn might stimulated the induction of reproductive phase, leaving less time for stem thickness during the autumn. While smooth and gradual rise in temperature, during crop life cycle of spring, favored thick stem with greater height. Taller plants produced in spring were attributed to longer crop growth duration and favorable crop growth conditions during vegetative growth period. Higher plant height, dry matter production and achene yield during spring was related to life cycle and total heat units accumulated by the crop (Table III; Hassan *et al*., 2005).

Yield and related traits: Crop characteristics are modified by environmental factors. Head diameter, achene number per head, achene weight and achene yield remained higher for spring-sown sunflower than these sown in autumn. Seasonal differences in biomass, yield and leaf area development showed better environment-driven resource (temperature, light, photoperiod & soil water) capture and utilization during spring sowing (Agele, 2003).

High harvestable yield is the ultimate purpose of growing crops. Crop growth and yield attributes are influenced by various seasonal factors. Early sowing of sunflower (spring sowing) produced more achenes per head and high achene weight resulting in substantial yield increase in economic yield (Jose *et al*., 2004). Season with

Fig. 1: Leaf area (cm^2) of sunflower hybrids during spring and autumn seasons
(Source: Kaleem *et al*., 2009)

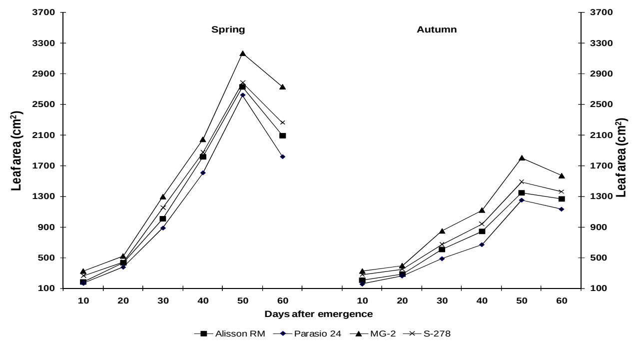
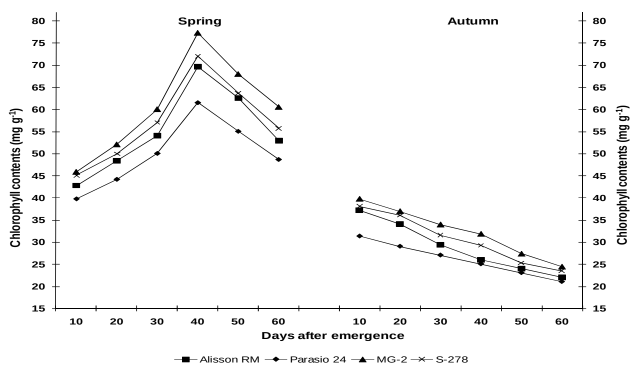


Fig. 2: Chlorophyll contents (mg g^{-1}) of sunflower hybrids during spring and autumn seasons
(Source: Kaleem *et al*., 2009)



high temperatures and low relative humidity at the time of pollination (autumn season) affects pollen vigor, causing poor pollination, produces low weight and infertile achenes ultimately leading to head fertility and low achene yield (Miralles *et al*., 1997).

Reproductive phase of crop is more sensitive to cold condition than vegetative phase, which results in floral abortion, poor seed set, infertile pollens and empty seeds with reduced seed size that limit the production potential of the crop (Goyne *et al.,* 1989; Kaleem *et al*., 2009). Cold stress during the reproductive development of the crop causes poor grain set, which ultimately reduced grain yield in fall season. Reduction in grain set induced by cold stress varied widely in cultivars. Thus period from heading to anthesis was considered sensitive to cold temperature; the main reason of low achene yield of sunflower was failure of achenes set (Qadir *et al*., 2007).

Biomass production is positively correlated with temperature and photoperiod. Villalobos *et al*. (1996) recorded higher biomass and seed yield of spring than that of autumn. During summer season favorable conditions like higher temperature, low relative humidity and more sunshine hours during flowering and seed setting period resulted in increased seed set, higher seed weight and maximum seed yield than rainy season with relatively low temperature, higher relative humidity, lesser sunshine hours and higher rainfall during peak flowering period affecting pollen vigor and pollen movement (Sumangala & Giriraj, 2003; Kaleem *et al*., 2009). Spring sowing was more suitable than autumn sowing in accumulation of maximum biological yield potential (Smiderle, 2001).

High temperature during 0-45 DAS shortened the emergence period, head initiation and crop growth duration, which decreased seed yield of monsoon sown crop, while maximum vigor, plant growth, crop growth rate and achene yield was recorded in the plots sown in spring (Caliskan *et al*., 2002). Sunflower sown at different times (spring & autumn sowings) performed differently seed yield, growth and development was significantly affected and decreased with delayed sowing, because of decrease in number of seeds per head and 100 seed weight (Kaleem *et al*., 2009).

Seasonal variation and physiological attributes: Weather change affects seasonal activity where temperature plays important role in plant developmental processes and leads to earlier switching to next ontogenetic stage. Climatic changes have major impacts on plant functioning, productivity and competition between plant species. The rates of chemical reactions are temperature dependent and increase with increasing temperature as low temperature is one of the limiting factors adversely affecting the physiological processes of plants (Franz *et al*., 2004). Various molecular, biochemical and physiological phenomena affect plant growth and development (Razmjoo *et al*., 2008).

Photosynthesis: Stomatal regulation is the key process in transpiration and photosynthesis. Both internal CO_2 concentration and photosynthesis may be reduced upon stomatal closure during any increase in air and soil temperature (Jarvis *et al*., 1999). In sunflower leaves, mesophyll conductance is usually high at higher temperatures; however it declines rapidly with decrease in temperatures (Oja *et al*., 1988).

Chlorophyll content is photosynthetic pigment and essential components of plant photo system, positively correlated with photosynthetic rate. Higher chlorophyll content in plants can collect and transfer more light energy, consequently enhancing photosynthetic efficiency. Changes in the amounts of photosynthetic pigments are closely associated to plant biomass yield (Jaleel *et al*., 2009). Gradual rise in temperature caused an increase in chlorophyll content up to maximum temperature (34.24°C) further increase in temperature decreased this content (Kaleem *et al*., 2009). Leaves from plants grown at lower temperatures had less chlorophyll than those grown at higher temperature. The higher rates of photosynthesis were accompanied by an increase in chlorophyll contents, thus enhanced the ability of plant for higher assimilation rate (Kingston *et al*., 1999). Chlorophyll contents are affected by growth stages, which decrease with the age of plant (Fig. 2; Kaleem *et al*., 2009). Chlorophyll contents decreased from anthesis to physiological maturity by an average of 23% in

Fig. 3: Photosynthetic rate (μmol CO_2 m^{-2} s^{-1}) of sunflower hybrids during spring and autumn seasons
(Source: Kaleem *et al*., 2009)

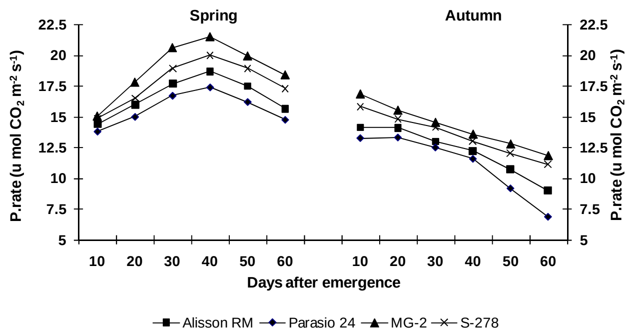
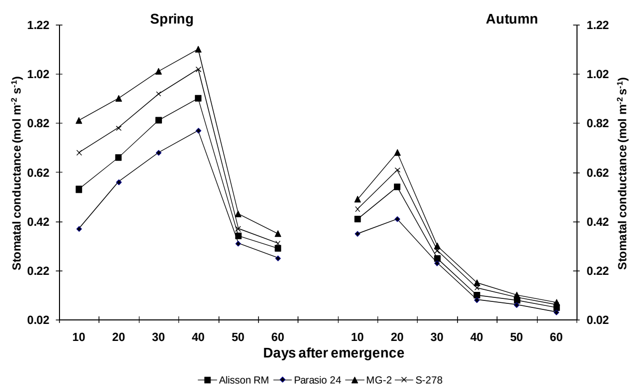


Fig. 4: Stomatal conductance (mol m^{-2} s^{-1}) of sunflower hybrids during spring and autumn seasons
(Source: Kaleem *et al*., 2009)



sunflower (Dordas & Sioulas, 2008).

Phtotosynthetic rate can be used as tool for selection of new sunflower varieties with high yield and high oil content under rainfed condition (Dordas & Sioulas, 2008). Plants grown at lower temperatures had decreased rate of CO_2 fixation together with decreased quantum efficiencies of photo system (PS) in the light although there was no photo inhibition (Kingston *et al*., 1999).

Water relations: Plant transpiration is a physical process in which part of the net radiation energy is converted into latent heat, under physiological control by changes in stomatal aperture. Increased stomatal conductance resulted in increased transpiration rate and low leaf water potential (Bunce, 2007). Variation in climatic factors affects photosynthesis and transpiration in different ways (Reddy *et al*., 2004).

Stomatal conductance was progressively increased due to the gradual increase of temperature up to 40 days after emergence (DAE) during spring season but from 50 DAE, it started decreasing, probably due to extreme temperature at this peak growth period. While due to increased temperatures, there was gradual increase in stomatal conductance up to 20 DAE; after which a gradual decrease was noted owing to gradual decrease in ambient temperature (Fig. 4; Kaleem *et al*., 2009). Moreover increase in the water stress levels also reduced the stomatal conductance. Kaleem *et al*. (2009) observed a linear relationship between photosynthesis and stomatal conductance (gs), which represents the contribution of gs on photosynthetic CO_2 assimilation.

Decrease in leaf relative water contents (RWC) decreased the stomatal conductance, which ultimately lowered the photosynthetic activity (Lawlor, 2002). Higher sucrose, chlorophyll and relative water contents resulted at warmer as compared to those at cooler condition. However chlorophyll content decreased to a significant level at higher water deficits in sunflower plants (Kiani *et al.*, 2008).

Assimilate partitioning: Maximum assimilate translocation takes place at optimum than at extreme temperatures (Hikosaka *et al*., 2006). Different temperatures affect photosynthetic rate differently, that is photosynthetic rate increased with increase in temperature (Kaleem *et al*., 2009; Fig. 3). Similarly, export of carbon from sunflower leaves at 13^{o}C was markedly less than at 30^{o}C (Paul *et al*., 1990). This rapid suppression of carbon export at lower temperature in sunflower was due to the reduced rate of translocation. Thus assimilate utilization is decreased at low temperature imposing a greater restriction on biomass production than at high temperature, because plants grown between 13°C to 23°C accumulated much less carbohydrates than those grown at 30^{o}C (Paul *et al*., 1990). This confirms that low temperature imposes a sink limitation on photosynthesis and this limitation may be relieved by decreasing the source to sink ratio (Mathew *et al*., 1992).

CONCLUSION

Environmental changes affect morphological, physiological, quantitative and qualitative traits in sunflower. Seasonal differences in biomass, yield and leaf area development show better environment-driven resource (temperature, light, photoperiod & soil water) capture and utilization during spring sowing. However autumn crop may be grown in low rainfall areas, where spring crop fails due to lesser rains as an alternate crop to those of traditional crops such as sorghum and millet.

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