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Evaluation of the OILCROP-SUN model for sunflower hybrids under different agro-meteorological conditions of Punjab—Pakistan

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ABSTRACT

Crop models and decision support system can be useful tools for researchers, teachers, scientists, extension educators, policy makers and planners to help or support the application and evaluation of sustainable and long term alternative management practices. Sunflower is an important oilseed crop that has the potential to bridge the gap between the consumption and domestic production of edible oil in developing countries such as Pakistan. Limited research has been conducted on the application of the OILCROP-SUN model for the simulation of growth and development of sunflower under different environmental conditions, especially in developing countries. Field experiments were conducted in three environments to study the impact of nitrogen (N) fertilizer on grain yield and quality. The objective of the present study was to evaluate the performance of the OILCROP-SUN model and to determine the effect of N on sunflower for three contrasting environments. The results showed that OILCROP-SUN model simulated well for growth, development and yield of sunflower hybrids in these three contrasting environments and under different management practices that included several genotypes and different nitrogen fertilizer application rates. The *d* values (index of agreement) for leaf area index (LAI) ranged from 88 to 97 under arid, 78 to 85 under semi- arid and 71 to 81 under sub- humid conditions. Similarly, *d* values for total dry matter (TDM) ranged between 90 and 94 under arid, 81 and 88 under semi-arid and 90 and 96 under sub-humid conditions, respectively while the percentage difference for grain yield ranged from 8.5 to 21% for different ecological conditions. The model also simulated LAI, TDM, grain yield and oil quality well under different environmental conditions of Pakistan and further studies should focus on application of the OILCROP-SUN model for variable agro-climatic regions where sunflower is an important crop.

1. Introduction

Sunflower is widely grown throughout the world due to its high oil quality associated with relative concentration of oleic and linolic acid. Sunflower oil contains about 85–90% unsaturated fatty acids and 10–15% saturated fatty acids (Flagella et al., 2002; Vega and Hall, 2002). It is grown in two seasons, spring and autumn, due to its wide range of climate adaptability (Katerji and Rana, 2006; Yau, 2007; Ahmad et al., 2009; Belhouchette et al., 2012). According to GOP (2015), the local production of edible oil was 0.573 M tons during 2013–14, while import of oil/oilseeds was 2.627 M tons. The edible oil import bill during 2013–14 was PKR. 246.895 billion/US$ 2.5 billion (GOP, 2015). In the world, sunflower was planted on area of 25.50 M ha with total production from this areas was 1.56 M tons (National Sunflower Association, 2015). Sunflower was planted on an area of 144 M ha with total production of 178 M tons and 68 M tons for seed and oil, respectively (GOP, 2015). There are many problems for sunflower production in Pakistan, some of them are the unavailability or high prices of inputs, traditional methods of sowing and harvesting, post harvest and marketing problems and

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Table 1
The summary of experimental locations of Punjab—Pakistan.

Experimental Locations	Multan (arid conditions)	Faisalabad (Semi arid conditions)	Gujranwala (Sub humid conditions)
Latitude (N°)	30°.18″	31°.40″	32°.19″
Longitude (E°)	71° 48″	73°.11″	74°.17″
Altitude (m)	123	184	221

last but not least, the unawareness of the farmers about the latest sunflower production technology (Badar et al., 2002; Shah et al., 2005).

Nitrogen (N) is the most important nutrient for increasing growth and yield of all field crops including sunflower. The sensitivity of N fertilizer has great importance not only in all types of crop plants but as a whole in agriculture sector. Application of N fertilizer increases the rate of photosynthesis, leaf production, development of individual leaf area and total leaf area (Bange et al., 2000; Jesus et al., 2001; Rouphael et al., 2007), resulting in higher light interception to fulfill the process of photosynthesis (Ferreira and Abreu, 2001; Rondanini et al., 2007) and again N fertilizer impact varied in its role with respect to age of crop as well as the agro-climatic conditions of the locality (Nasim et al., 2011, 2016). The metabolic processes that increase vegetative, reproductive growth and yield of the crop are totally dependent upon the amount of nitrogen fertilization. With increasing N fertilizer, there is concurrent increase in growth, development and photosynthesis of the crop (Steer and Hocking, 1985; Sinsawat and Steer, 1993). N fertilizer application affects all the processes of dry matter production, N accumulation and partitioning into various parts of crop plants (Steer et al., 1985a; Steer et al., 1985b; Steer et al., 1986; Veerana and Steer, 2003).

Crop simulation models have been used for many different applications in various countries around the world. The Decision Support System for Agrotechnology Transfer (DSSAT v4.5, Hoogenboom et al.,1999, 2010) is a comprehensive system (Tsuji et al., 1994; Jones et al., 2003; Hoogenboom et al., 2004; Phakamasa et al., 2013) that also includes the OILCROP-SUN model (Villalobos et al., 1996; Rinaldi et al., 2003). Crop growth and development are simulated by the OILCROP-SUN model from planting to maturity with a daily time step and are based on physiological processes that describe the response of sunflower to soil and aerial environmental conditions. Potential growth is dependent on photosynthetically active radiation (PAR) and its interception, whereas actual biomass production on any day is constrained by suboptimal temperatures, soil water deficits, and nitrogen deficiencies. The input data required to run the DSSAT models include daily weather data (maximum and minimum temperature, rainfall, and solar radiation); soil data (physical, chemical, and morphological properties); a set of cultivar coefficients (Aguera et al., 1997; Tyagi et al., 2000; Anothai et al., 2008; Hoogenboom et al., 2010), being grown in terms of plant development and grain biomass; and crop management information, such as plant population, row spacing, seeding depth, and application of fertilizer and irrigation. A detailed description of the OILCROP-SUN model can be found in Villalobos et al. (1996), Aguera et al. (1997), Moriondo et al. (2003), Rinaldi et al. (2003) and Ahmad et al. (2013).

The OILCROP-SUN model has been tested extensively for different soil types; its performance was reasonably good and for a range of climatic conditions and with various sunflower hybrids (Sinclair and Seligman, 1996; Stockle et al., 2003). Studies on the use of crop growth modeling for assessing the effect of nitrogen use efficiency on sunflower hybrids in different agro-ecological environment was observed very rare in Pakistan. In previous studies simulated yield predicted by the model was compared with observed yield (Sinclair and Seligman, 2000; Zalud and Dubrovsky, 2002; Solar et al., 2008; Usman et al., 2009) to find out gap between potential yield and actual yield obtained from the experiments. In Pakistan and similar environments in south Asia, limited studies for sunflower grown in contrasting environments, has been reported yet. The present study was, therefore, conducted with the objective to evaluate the performance of OILCROP-SUN model for its ability to simulate growth, development and achene yield for sunflower hybrids under arid (Multan), semi-arid (Faisalabad) and sub-humid (Gujranwala) conditions of Punjab, Pakistan.

2. Material and methods

2.1. Experimental sites and soils

The experiments were conducted during the spring seasons of 2008 and 2009 at the Central Cotton Research Institute (CCRI), Multan (30°.18″N, 71°.48″E), the Agronomic Research Area, University of Agriculture Faisalabad (31°.40″N, 73°.11″E), and the Adaptive Research Farm, Gujranwala (32°.19″N, 74°.17″E), Punjab—Pakistan. In these locations, there were differences among the soils for all the experimental locations as shown by the soil analysis data described in Table 1. To determine the soil characteristics, soil samples were collected at different locations in each field prior to planting at depths of 0–15, 15–30, 30–45, 45–60, 60–75, 75–90 and 90–105 cm. The soil samples were analyzed for texture, soil moisture, soil pH, organic matter, exchangeable potassium (K) and phosphorus (P), and nitrate (NO_3) and ammonium (NH_4^+) concentrations as explained in Table 2. The data for 2008 season were used for calibration to determine the cultivar coefficients, while data collected during the 2009 season were used for evaluation of the model.

2.2. Experimental design and crop husbandry

The experiments were laid out in randomized complete block design in split plot arrangement with three replications; hybrids were in the main plots and nitrogen levels in the subplots. There were fifteen treatments, including five nitrogen (N) levels (0, 60, 120, 180 and 240 kg ha^{-1}) and three sunflower hybrids (Hysun-33, Hysun-38 and Poineer-64A93) at all three contrasting environments. Phosphorus (P) and Potassium (K) were used at the rate of 60 kg ha^{-1} each, in all plots. N, P, and K, were applied in the form of urea, triple super phosphate and sulphate of potash (K_2SO_4). 1/3rd dose of nitrogen and all of the P and K fertilizer was applied at the time of sowing, while remaining 2/3rd of nitrogen was used in two splits; first dose at first irrigation and second dose of N at the flowering stage (3rd irrigation) of crop at all the experimental sites during both years. The net plot size was 4.2 m × 5 m. Seeds were planted with a hand mounted seed drill (dibbler) keeping one seed per hill at a distance of 20 cm between hills using a recommended seed rate of 7 kg ha^{-1}. Furthermore, all the procedures that were used to conduct the experiment were discussed in further detail by Nasim et al. (2011, 2012, 2016). The experiments were well managed to obtain optimum conditions for plant growth and development, and to avoid any stresses due to water, pests, disease and other crop limiting factors that could affect any reduction in yield. Data were collected on plant growth and development, soil characteristics, weather and crop management as required for determining the cultivar coefficients of a new sunflower hybrid, using the practice recommended IBSNAT (1988), Hoogenboom et al.