Seed Yield and Quality of Sunflower (*Helianthus annuus* L.) as Influenced by Staggered Sowing and Organic Fertilizer Application in the Humid Tropics

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Citation Information: Helia. Volume 37, Issue 61, Pages 237–255, ISSN (Online) 2197-0483, ISSN (Print) 1018-1806,DOI: 10.1515/helia-2014-0012, October 2014

Publication History

Received:
2014-06-06
Accepted:
2014-09-16
Published Online:
2014-10-04

Abstract

Two field experiments were conducted on the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta (7° 15′ N, 3° 25′ E, altitude 140 m above sea level) in south western Nigeria between June and November,2012 to evaluate the performance of two sunflower varieties (SAMSUN-3 and Funtua) as affected by different sowing dates and organic fertilizer application. The experiment was laid out in split–split plot design with sowing dates as main plot, organic fertilizer as sub-plot and variety as sub-sub-plot, and replicated three times. Sowing date significantly ($P \leq 0.05$) increased and reduced number of phenological days to flowering of early and late sown sunflower, respectively. Funtua (a local adapted variety) matured 7 days later than SAMSUN-3 (recently released variety) when sown late. Application of organic fertilizer significantly ($P \leq 0.05$) increased plant height of early and late sown sunflower. Delay in sowing till first week in September significantly ($P \leq 0.05$) reduced head diameter, number of seeds per head and seed yield of late sown sunflower. Oil and protein contents of seeds from early and late sown sunflower plants were significantly ($P \leq 0.05$) increased by organic fertilizer application, except protein content of late sown sunflower. However, it significantly ($P \leq 0.05$) increased oil yield by 23% relative to the control in the late sown sunflower. Based on the comparatively high seed yield (850.45–1,525.78 kg/ha) recorded in our study, it is recommended that sunflower be sown in the forest–savanna transition zone in early July or second to third week in August.

Keywords: organic fertilizer; oil content; protein content; staggered sowing; sunflower

Introduction

Sunflower (*Helianthus annuus* L.) occupies the fourth position among vegetable oilseeds after soybean, oil palm and canola in the world (Rodriguez *et al*., 2002 and Ahmad *et al*., 2011). Although sunflower is generally regarded as a temperate zone crop, it is currently cultivated on approximately 23 million hectares in 40 countries of the world, including some countries in the humid tropical Africa because it is quite rustic and can perform well under varying climatic and soil conditions (Seiler *et al*., 2008, Kaleem *et al*., 2011b). The major goal of growing sunflower is for its seed (achene) that contains oil (36–52%) and protein (28–32%) as reported by Rosa *et al*. (2009). The crop has been receiving steady attention by various scientists from diverse disciplines in recent past because sunflower oil is a premium oil with light colour and is widely used in the diets of heart patients because it contains very low cholesterol and high (90%) unsaturated fatty acid concentration (Flagella *et al*., 2002; Qahar *et al*. 2010). In recent past, there has been a steady increase in demand for organic foods globally because of the health risks posed by conventional method of production (Yiridoe *et al*., 2005). After reviewing 343 studies, it was revealed that organic crops and crop-based foods contain up to 60% higher key antioxidants than conventionally grown crops (Baranski *et al*., 2014). We therefore decided to explore the potential of organic sunflower in the transition zone. The productivity of sunflower in terms of seed yield, oil and protein output varies widely depending on multifarious factors of the environment such as radiation (Dosio *et al*., 2000), temperature (Kaleem *et al*., 2009 and 2011a), rainfall distribution (Lawal *et al*., 2011;Asbag *et al*., 2009; Olowe *et al*., 2013), agronomic practices like time of sowing (de la Vega and Hall, 2002; Lawal *et al*., 2011; Anjum *et al*., 2012), plant density and nitrogen nutrition (Ali *et al*., 2012), varying planting pattern (Yasin *et al*., 2013) and sowing of improved varieties and hybrids (Ali *et al*., 2011). Consequently, there is a disparity among the reported African (812 kg/ha) and Nigerian (1,000 kg/ha) averages by Olowe *et al*. (2013) and the world average of 1,520 kg/ha (USDA, 2012).

Although much work has been done on sunflower agronomy in different agro-ecological locations of the world with a view to gaining insight into the effects of the cultural practices that enhance seed yield, there is still a dearth of information on the performance of newly released and improved, and locally adapted sunflower varieties as affected by organic fertilizers and varying sowing dates in the forest–savanna transition zone which is outside its traditional growing region (savanna). Earlier research works on sunflower agronomy in the tropics reported varying optimum rates of nitrogen fertilizer to be 60 kg N/ha in Nigeria (Olowe *et al*., 2005), 80 kgN/ha in India (Rasool *et al*., 2013), 150 kgN/ha at Islamabad, Pakistan (Bakht *et al*., 2010) and 180 kgN/ha at Faisalabad, Pakistan (Nasim *et al*., 2012b). Sunflower growers rarely apply organic fertilizers to sunflower despite the inherent advantage (slow nutrient release and potential improvement of soil structure and water holding capacity) of organic plot compared with the conventional plot (Posner *et al*., 2008). In fact, the resource-constrained farmers in the tropics seldom apply mineral fertilizers because of restricted access to the input and its exorbitant cost. Different brands of organic fertilizers using plant residues, municipal and abattoir wastes are now being produced in Nigeria for farmers' use in crop production and they are significantly cheaper that mineral fertilizers. Unfortunately, information is lacking on the response of sunflower to organic fertilizer application in humid tropical Africa. Recent work in India reported linear increase in seed yield as farmyard manure rate increased from 10 to 20 ton/ha, suggesting that an additional increase in seed yield with increase in rate of farmyard manure (Rasool *et al*., 2013). Similarly, plant population density (Olowe, 2005; Petcu*et al*., 2010) and planting ratio (Shakuntula *et al*., 2012) studies also indicated varying results in different locations. Optimum sowing date of sunflower as early and late season crops is relatively well known to be late May and July – Early August, respectively in the forest–savanna transition zone (Ogunemi, 2000). The seed quality of sunflower is a function of an inter play of the genetic, environmental and agronomic manipulations (Baydar and Erbas, 2005; Petcu*et al*., 2010; Olowe *et al*., 2013). However, most of the studies conducted in the humid tropics neither related the performance of sunflower to the phenology of the crop nor ascertained the quality of the seeds after imposing the various treatments. Furthermore, attempts have not been made to exploit the possibility of having two good quality sunflower crops in a year by staggering sowing dates. Consequently, part of what is still lacking now in the agronomy of sunflower in the humid tropics is a comparative study that will provide an insight into the effects of some weather parameters and manipulation of cultural practices on the phenology, seed yield and quality of sunflower. The hypothesis of the study was hinged on possibility of growing more than one crop of sunflower in a year. Therefore, this study was carried out to determine the effects of staggered sowing and organic fertilizer application on growth, development, seed quality and yield of two sunflower varieties in a forest–savanna transition zone of the tropics.

Materials and methods

Growth conditions

The field studies were conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta (7° 15′ N, 3° 25′ E, altitude 140 m above sea level) in south western Nigeria on a loamy sand soil between June and November, 2012. The two test varieties were Funtua, a locally adapted, late-maturing variety (110–120 days) and SAMSUN-3, also late maturing (110–120 days), drought tolerant and contains good antioxidants (NASC, 2013). The soil characteristics of the two experimental plots are shown in Table 1. The soils of the experimental sites were loamy sand in texture and low to medium in nitrogen and phosphorus, and adequate in potassium based on rating for soil fertility classes as described by Anon (1989). The meteorological data for the growth period of the two experiments were collected from the Department of Water Resources Management and Agrometeorology located about 300 m away from the Research Farm. The experimental site was located in the forest–savanna transition zone with a traditional bi-modal rainfall distribution having peaks usually in July and September and a short dry spell often referred to as *august break*. Weather data during the two periods of experimentation in 2012 are presented in Tables 2–4. The months of July (155.4 mm) and October (184.7 mm) were the wettest months during the growing periods of early and late sown sunflower. The coolest and hottest months based on mean atmospheric temperature were August (25.4°C) and November (28.2°C). Relative humidity values, however, ranged between 77.5% (October) and 82.6% (August) as shown in Table 2. The amount of rainfall received by early and late sown sunflower, number of rainy days and daily sunshine duration decreased as sowing was delayed (Table 3). The growing degree days (GGD) values for early and late sown sunflower varieties during the four sowing dates are presented in Table 4. The values ranged between 2,073.39° and 2,423.07°C and 1,942.37° and 2,038.43°C for the early and late sown SAMSUN-3 variety, respectively. While for Funtua, the values were 2,067.90°–2,370.06°C and 2,052.29°–2,189.27°C for the early and late sown sunflower, respectively.

Tab.

Table 1:

Some physico-chemical characteristics of the experimental fields (0–30 cm level)

Tab.

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Table 2:

Rainfall distribution (mm), mean monthly temperature (T°C) and relative humidity(RH, %) during period of experimentation in 2012

Tab.

*2

Table 3:

Rainfall distribution, number of rainy days and total daily sunshine duration across four planting dates of early and late sown sunflower

Tab.
*3

Table 4:

Growing degree days (GDD) of early and late sown sunflower varieties across sowing dates

Experimental design and measurements

The two field experiments were laid out in a split–split plot design with three replications. The treatment combinations were 16 comprising of four main plots (sowing date at weekly interval: I, II, III and IV: 19, 26 June, 3 and 10 July and 14, 21 and 28 August and 4 September for early and late sown sunflower, respectively), two sub-plots: Control – no fertilizer applied and organic fertilizer application at 50 ton/ha equivalent to 60 kgN ha^{-1} of mineral fertilizer rate recommended for sunflower (Olowe *et al*., 2005) and two sub-sub-plots (SAMSUN-3 and Funtua) varieties. The organic fertilizer ("*Aleshinloye*" Fertilizer) used contained 1.2% N, 76 ppm P, 13.75 cmol K and 10.28 cmol Na.

Crop husbandry

The experimental sites were ploughed twice and harrowed once before marking out the plots. At each sowing date, seeds of the test varieties were sown at a spacing of 60 cm×30 cm which corresponded to 56,000 plants ha^{-1}. Three seeds of the test varieties were sown per hole and later thinned to one plant per stand at 2 weeks after sowing (WAS). Each experimental plot consisted of four rows 5 m in length and measured 1.8 m×5 m (9.0 m^2). No agro-chemicals were used during both experiments in order to simulate the usual practice of the resource-constrained farmers. Organic fertilizer was applied and incorporated into the soil during seedbed preparation a week before sowing. Manual weeding was done at 3 and 6 WAS and five randomly selected plants were tagged from the middle rows of each plot for plant height measurement at flowering (R5–when 30–80% of disk flowers have completed flowering on the inflorescence) and physiological maturity (R9–when the bracts are yellow and brown) as described by Schneiter and Miller (1981). The tagged plants were later harvested and used for yield component analysis. The crop was grown under rain-fed conditions which is the usual practice of the resource-constrained farmers. There were no incidences of pests and diseases during the early and late sown cropping. This could be attributed to the fact that sunflower is still alien to this agro-ecological zone.

Data collection

The characters determined on plot basis were number of phenological days to flowering (R5) and physiological maturity (R9), plant height (cm), i.e. height from the soil surface to the tip of the head at

R5 and R9, head diameter (cm), head weight (g), number and weight (g) of seeds per head, 100 seed weight (g), seed yield (kg ha^{-1}), oil and protein contents (%) in the seed and oil yield (kg ha^{-1}). Plant height, seed yield and yield components were determined on the five earlier tagged plants on plot basis. Heat unit accumulation measured as GDD was determined using the equation of McMaster and Wilhelm (1997) as: $GDD=(T_{max}+T_{min})/2-T_{base}$ T_{base} was taken as 7.2°C based on several studies of heat units as adopted by Agele (2003) and Canavar *et al*. (2010). Values of GDD recorded for early and late sown sunflower across the four sowing dates are presented inTable 4.

The oil and protein contents of seed were determined using Soxhlet extraction with petroleum ether as the solvent and Kjeldahl block digestion and steam distillation as described by Eglan *et al*. (1981), respectively. The materials used for protein determination included digestion block, digestion tubes, Kjeldahl distillation unit and automatic titrator.

Data analysis

The data collected were statistically analysed using the MSTATC package (Freed *et al*., 1989) and significant (P<0.05; F-test) treatment means of the main effects and interactions were separated using the least significant difference method at 5% probability level.

Results

Effect of staggered sowing and organic fertilizer application on phenology and height characteristics of early and late sown sunflower

Sowing date significantly (P≤0.05; F-test) affected number of phenological days to flowering of early and late sown sunflower and number of phenological days to physiological maturity of late sown sunflower (Table 5). However, sowing date had no significant effect on height at flowering and physiological maturity of both early and late sown sunflower. Organic fertilizer application significantly (P≤0.05; F-test) reduced number of phenological days to flowering of early sown sunflower and increased plant height at flowering and physiological maturity of both early and late sown sunflower. Similarly, variety effect was significant (P≤0.05; F-test) on plant height at flowering and physiological maturity of both early and late sown sunflower with Funtua recording higher values for these traits than SAMSUN-3. Funtua also attained flowering and physiological maturity later than SAMSUN-3 (significant at$P$<0.05) during the early and late sowing, respectively. Plant height at flowering and physiological maturity of late sown sunflower were significantly (P≤0.05; F-test) affected by sowing date×fertilizer and sowing date×variety interactions, respectively (Table 5). Since fertilizer×variety and sowing date×fertilizer×variety effects were not significant for all the traits evaluated in our study, they are not presented in Tables 5–7, except Fertilizer×Variety effect on number of seeds per head in Table 6.

Tab.
*4
Table 5:

Effects of staggered sowing, organic fertilizer application and variety on plant height and number of phenological days to flowering (R5) and physiological maturity (R9) of early and late sown sunflower

Tab.
*5
Table 6:

Effects of staggered sowing, organic fertilizer application and variety of sunflower seed yield, yield attributes and seed quality of early sown sunflower

Tab.
*6
Table 7:

Effects of staggered sowing, organic fertilizer application and variety of sunflower seed yield, yield attributes and seed quality of late sown sunflower

Effect of staggered sowing and organic fertilizer applicationon seed yield, some yield attributes and seed quality of early and late sown sunflower

Sowing date did not affect seed yield, yield attributes and quality of sunflower, except protein content ($P \le 0.05$; *F*-test) of early sown sunflower (Table 6). However, application of organic fertilizer significantly ($P \le 0.05$; *F*--test) affected seed yield, yield attributes and quality of early sown sunflower, except oil yield. Application of organic fertilizer resulted in significantly ($P<0.01$) higher values for all the traits measured relative to the control, except oil yield. Variety effect was not significant for any of the traits evaluated. Among the interaction effects, only sowing date×variety and fertilizer×variety were significant ($P \le 0.05$; *F*-test) for number of seeds per head of early sown sunflower, respectively (Table 6). Staggered sowing of sunflower in the late season significantly ($P \le 0.05$; *F*-test) affected head diameter, number of seeds per head and seed yield (Table 7). Application of organic fertilizer significantly ($P \le 0.05$; *F*-test) increased seed yield, all yield attributes, oil yield and seed quality of late sown sunflower, except protein content. Varietal effect was only significant ($P \le 0.05$; *F*-test) on head diameter with SAMSUN-3 producing head with higher diameter. Sowing date×fertilizer interaction significantly ($P \le 0.05$; *F*-test) affected oil and protein content of late sown sunflower. Whereas, sowing date×variety interaction significantly ($P \le 0.05$; *F*-test) affected head diameter and head weight of late sown sunflower (Table 7).

Effects of sowing date×organic fertilizer on plant height at flowering and seed quality of late sown sunflower

The mean values of plant height at flowering and seed quality (protein and oil contents) that were significantly ($P<0.05$; *F*-test) affected by sowing date×organic fertilizer application interaction effects of late sown sunflower are presented in Table 8. Fertilized sunflower sown between 14 and 28 August recorded significantly ($P \le 0.05$) higher plant height at flowering than the fertilized sunflower sown on 4 September and unfertilized sunflower sown on 21 August and 4 September. The protein content of fertilized sunflower sown on 28 August was significantly ($P \le 0.05$) higher than the other treatments, except the unfertilized sunflower sown on 14 August. However, the oil content of fertilized sunflower sown on 21 and 28 August was significantly ($P \le 0.05$) higher than all the unfertilized sunflower treatments, except the sunflower sown on 14 August (Table 8).

Tab.
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Table 8:

Effects of sowing date×organic fertilizer on plant height at flowering (R5), protein and oil content of late sown sunflower

Effects of sowing date×variety on number of seeds per head of early sown sunflower and some yield attributes of late sown sunflower

Funtua variety sown on 26 June produced significantly ($P \le 0.05$) higher number of seeds per head than SAMSUN-3 sunflower variety sown on the same date. Plants of Funtua variety sown on 28 August were significantly ($P < 0.05$) taller than all the plants of SAMSUN3 and Funtua varieties sown across all the sowing dates, except Funtua sown on 14 August (Table 9). The latest sown Funtua variety (4 September) produced significantly ($P \le 0.05$) smaller head diameter and smaller head weight than those of other treatments, except SAMSUN-3 sown 3 July.

Tab.
*8
Table 9:

Effects of sowing date×variety on number of seeds per head of early sown sunflower and plant height at physiological maturity (R9), head diameter and average head weight per plant of late sown sunflower

Effects of organic fertilizer application×variety on number of seeds per head of early sown sunflower

Mean values of seeds per head of early sown sunflower varieties as affected by organic fertilizer×variety interaction are presented in Table 10. On average, the fertilized treatments of SAMSUN-3 and Funtua produced significantly ($P \le 0.05$) higher number of seeds than their unfertilized treatments by 16.6 and 13.8%, respectively.

Tab.
*9
Table 10:

Effects of organic fertilizer×variety on number of seeds per head of early sown sunflower

Discussion

The productivity of sunflower is largely determined by the prevailing weather conditions throughout its life cycle and imposed cultural practices (Kaleem *et al*., 2011a). Cultural practices like sowing date and fertilizer application and some environmental factors (temperature and rainfall) are major factors which affect plant growth and development. In our study, varying responses were observed on the two test varieties to these factors. Although, temperature is not a limiting climatic factor in the tropics, delay in sowing resulted in lower values of GGD of late sown sunflower, especially Funtua (late-maturing variety). The overall range of total GGD of 1,942.37–2,423.07 compared favourably with values (2,187.00–2,293.30) reported for sunflower hybrids in Berlin by Canavar *et al*. (2010) and higher than values, 1,656.0–1,890.0 and 1,469.0–1,598.0 recorded for sunflower hybrids in Pakistan during spring and autumn, respectively (Qadir *et al*., 2007). Sunshine hour range of 300.6 to 497.0 from planting to maturity was much lower than 894.1–959.5 h recorded in Berlin by Canavar *et al*. (2010). The lower values could be attributed to heavier cloud cover in the tropics compared to the temperate region. As sowing was delayed, number of phenological days to flowering of early sown sunflower significantly ($P \leq 0.05$) increased. Whereas number of phenological days to flowering and physiological maturity of late sown sunflower significantly ($P \leq 0.05$) decreased. This trend could be attributed to increased vegetative growth in early sown sunflower relative to the late sown crop. Early sown Funtua variety flowered 4 days later than SAMSUN-3 and was also significantly ($P \leq 0.05$) taller at flowering and physiological maturity in both early and late sowing dates. However, Funtua matured 7 days later than SAMSUN-3 during late sowing. Application of organic fertilizer significantly ($P \leq 0.05$) hastened number of phenological days to flowering of early sown sunflower by 2 days and also enhanced plant height of early and late sown sunflower. The nutrients supplied through the application of organic fertilizer apparently enhanced the growth of sunflower. When sowing was delayed till 4 September, 2012 in the late sown sunflower, head diameter, number of seeds per head and seed yield were significantly ($P \leq 005$) reduced. However, organic fertilizer application significantly ($P \leq 0.05$) increased seed yield and yield attributes in both early and late sown sunflower. Increased seed yield in sunflower had also been attributed to increase in the values of seed yield attributes after nitrogen application (Bakht *et al*., 2010; Ahmad *et al*., 2011 andNasim *et al*., 2012b). Among the seed yield attributes evaluated, only number of seeds per head, head diameter and head weight were significantly affected by sowing date×variety interaction effect with Funtua recording higher values. Number of seeds per head had earlier been reported to contribute greatly to variation in sunflower oil yield by de la Vega and Hull (2002). In our study, the effect of sowing date, organic fertilizer application and variety on seed quality was variable. Sowing date did not affect oil and protein content of early and late sown sunflower, except protein content of early sown sunflower. Sunflower sown on 3 July, 2012 contained the highest protein (22.9%) and it compared favourably with values (17.25–18.89%) reported for hybrids in Pakistan (Ahmad *et al*., 2011) and on par with values (21.91–27.51%) in Moldova (Yasin *et al*., 2013). Application of organic fertilizer significantly ($P \leq 0.05$) increased oil and protein contents in both early and late sown sunflower, except protein content of late sown sunflower. Nasim *et al*. (2012a) also reported optimum oil content when nitrogen was applied at 60 kg/ha and a decline as N increased to 240 kgN/ha. A significant ($P \leq 0.05$) high protein content of 29.71%) was reported when N was applied at the rate of 150 kg/ha in Moldova (Yasin *et al*., 2013). The ultimate goal of growing sunflower is for edible oil contained in its seed and the oil yield is a function of the genotype, seed yield and oil concentration (de la Vega and Hall, 2002; Petcu *et al*., 2010). Delay in sowing in both early and late sown sunflower did not affect oil yield even though sowing date has been reported to be the main source of variation for oil yield by de la Vega and Hull (2002). Application of organic fertilizer significantly ($P \leq 0.05$) increased oil yield by 23% relative to the control in the late sown sunflower. The oil yield values of 213.56–381.46 kg/ha recorded on late sown sunflower compared favourably with values (226.42–302.91 kg/ha) earlier reported for sunflower sown between late July and early September in a forest location (Lawal *et al*., 2011). In the late sown sunflower, oil yield was higher in earlier than later sowing dates. This trend was consistent with findings in Serbia (Balalic *et al*., 2007, 2010) and Nigeria (Lawal *et al*., 2011). Only organic fertilizer application significantly ($P \leq 0.05$) affected both early and late sown sunflower seed yield. The response to applied fertilizer could be attributed to availability of nutrients in the soil during the physiological growth and development stages of the plants as recently reported by Yasin *et al*. (2013). The seed yield range (852.45–1,525.78 kg/ha) recorded in our study was on par with the Nigerian (1,000 kg/ha), African (812 kg/ha) averages (Olowe *et al*., 2013) and world average (1,520 kg/ha) according to USAD (2012). This performance confirmed the potential of sunflower especially when sown in early July or second to third week in August. The late season is usually the more preferred period to sow sunflower in the humid tropics because of the desire to harvest the heads in November/December when the weather is dry in order to get good quality seeds.

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