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Effects of Organic and Inorganic Fertilizer on Sorghum Yield and Growth Attributes: A Review

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Abstract

The continued use of imbalanced fertilizers results in soil acidification and nutrient depletion, which is a severe danger to environmental quality. Thus, the objective of this review was designed to review the influence of different organic manures in combination with inorganic fertilizer on the growth parameters, yield, and yield components of sorghum crops. As observed from the review, all parameters of sorghum are affected by the application of fertilizers. Application of inorganic fertilizers increased the yield and other parameters of sorghum plants above unfertilized treatments. By the same token, the application of organic manures increased the yield and other parameters of sorghum plants over the control treatments. As observed from several findings, N and P fertilizer produced the largest and most significant yield of sorghum, whereas other nutrients had no appreciable effect. Hence, the combining organic manures and inorganic fertilizer is one of the best options for the environment, saving the farmer costs, improving soil fertility status, and increasing the yield of plants. According to the review, the type of soil, agroecology, and plant variety all influence how plants react to fertilizer. It can be concluded that to maximize the production and productivity of sorghum plants while also improving soil health, it is necessary to set the optimal rate of organic manures and inorganic fertilizer as per the site-specific location.

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Sorghum, fertilizer rate, yield, plant growth, Sorghum bicolor (L.) Moench.

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench, Poaceae] is a significant C4 crop used mostly for human food, animal feed, forage, and fodder, but it is also a significant source of fiber and a key feedstock for the manufacture of biofuels (Bollam *et al.,* 2021). According to Morris *et al.,* (2013), sorghum is cultivated all over the world and distributed across different continents, including North America, Africa, Asia, and Australia. Dicko *et al.,* (2006) reported that most people in semi-arid tropical regions of Africa and Asia eat sorghum as their primary source of food. That is why increasing the resource-use efficiency, yield, and quality of grain sorghum would have an important effect on the world. Overall, sorghum can be productive even in adverse and marginal locations because it is generally known to have adapted to marginal soils with limited nutrient availability (Qi *et al.*, 2019). Fortunately, sorghum yields may rise dramatically with an appropriate amount of nutrients.

Application of fertilizer is crucial for increasing agricultural productivity, boosting yield by increasing nutrient availability, and raising soil resilience to climate change (Liu *et al.,* 2021). The continued use of imbalanced fertilizers results in soil acidification and nutrient depletion, which is a severe danger to environmental quality (Guo *et al.,* 2010). Additionally, Shisanya *et al.,* (2009) revealed inadequate fertilizer application exacerbates the effects of climate change on crop productivity. Even if the use of chemical fertilizers is believed to be helpful for increasing productivity, an overreliance on chemical fertilizers may negatively affect soil quality and crop production over time (Hepperly *et al.,* 2009).

According to Huang *et al.,* (2010), organic fertilizers significantly increase yields of crops and soil health. By improving nutrient availability and reducing nutrient losses, organic manure treatment significantly accelerates plant development (Ul-Allah *et al.,* 2015).

According to research by Aina *et al.,* (2019), organic fertilizers can increase crop yield, quality, and tolerance to a variety of adverse situations. Organic manures were employed by early farmers to increase the production of crops and to enhance the health of the soil. They were; however, slow to respond to increasing crop yield. Farmers now use inorganic fertilizers because they are quick-acting, affordable, and inexpensive because of current agricultural practices.

Issues with soil health and fertilizer leakage into underground lakes and rivers pose a major threat to both human and animal life (Mahmood *et al.,* 2017). It is consequently critical to strike a balance between both chemical and organic fertilizers in order to enhance crop growth without endangering soil fertility. As a result, this review's objective was to investigate the effects of various organic manures in conjunction with inorganic fertilizer on the growth characteristics, yield, and yield components of sorghum crops.

Effects of nitrogen fertilizer on sorghum yield and growth characteristics

Yield

As reported by Temeche *et al.,* (2021), sorghum grain yield increased as nitrogen application rates were raised a second time. They discovered that the application of 138 kg N ha^{-1} in two split doses of half dose at sowing and half dose at tillering resulted in the best grain production (5.836 t ha^{-1}), whereas the lowest grain yield (4.276 t ha^{-1}) was achieved from 0 kg N ha^{-1}. With higher applications of nitrogen fertilizer, the yield of crops rose. In the study conducted by Gebrelibanos and Dereje (2015), the treatment that received 150 kg ha^{-1} of nitrogen fertilizer had the greatest grain yield of sorghum (2231.48 kg ha^{-1}), whereas the treatment that received zero kg ha^{-1} of nitrogen fertilizer had the least grain yield. In another investigation, Sarmiso (2016) found that an application of 92 kg N ha^{-1} resulted in the maximum grain yield (5675.31 kg ha^{-1}), whereas no nitrogen fertilizer treatment resulted in the lowest grain yield (2777.22 kg ha^{-1}).

According to a report from ICARDA (2016), the highest possible grain yield of sorghum (3.7 t ha^{-1}) was obtained at 87 kg ha^{-1}of N with a split application of 1/2 at planting and 1/2 at knee height, while the smallest grain yield of sorghum (1.8 t ha^{-1}) was obtained at 87 kg ha^{-1}of N. Nitrogen fertilizer applied at a rate of 87 kg/ha increases sorghum yield by 1.9 t ha^{-1} more than the untreated treatment. Shibeshi *et al.,* (2022) devised the study to investigate the impact of nitrogen rates on yield and yield components of improved sorghum cultivars in three lower watersheds in Habru district, northern Ethiopia.

Accordingly, nitrogen rates (0, 46, 69, 92, and 115kg N ha^{-1}) and two sorghum types (Melkam and Girana1) were arranged in factorial combinations. As a result, data showed that 92 kg/ha nitrogen application with the Melkam variety resulted in the highest over-season and location-combined grain yield (5.2 t ha^{-1}), followed by 115 kg ha^{-1} with Melkam (4.15 t ha^{-1}), which was statistically equal to 92 kg ha^{-1} with Girana1, and the lowest grain yield (2.15 t ha^{-1}) was recorded from Girana1 unfertilized treatment.

Plant height

According to several research results, nitrogen treatments led to taller plants than nitrogen-free treatments. The tallest plant (145.83 cm), for instance, was recorded from 92 kg N ha^{-1} with 1/3 at sowing, 1/3 at early tillering, and 1/3 at tillering application, and the smallest plant (124.85 cm) was reported from unfertilized treatment (Temeche, 2021). In the other trial, the treatment that received 150 kg N ha^{-1} produced plants with the greatest height (137.04 cm), while the treatment that received no fertilizer produced the lowest-growing plants (120.83 cm) (Table 1).

The same result was found in Moraditochaee *et al.,* (2012) a significant increase in plant height in sorghum when supplied with higher amounts of nitrogen. The longest plant height (155 cm) was achieved from the 80 and 120 kg N ha^{-1} treatments, whereas the shortest plant height (144 cm) was obtained from the absence of fertilizer treatment (Buah *et al.,* 2012).

Panicle length

According to Shibeshi *et al.,* (2022), Melkam with 92 kg N ha^{-1} had the longest panicle length (0.39 m), whereas Girana1 with zero nitrogen had the smallest (0.22 m). In the other trial, the 150 kg N ha^{-1} had the longest panicle length (17.03 cm); however the control had the smallest panicle length (21.25 cm) (Table 1). The 150 kg N ha^{-1} produced the longest panicle length (30 cm), while the control produced the shortest panicle length (28 cm) (Fantaye, 2018).

Biomass yield

In the study conducted by Shibeshi *et al.,* (2022), the highest above-ground biomass (41.61 t ha^{-1}) was recorded from Girana1 using 92 kg N ha^{-1}, which is statistically equivalent to Girana1 using 115 kg N ha^{-1}, and the lowest (14.88 t ha^{-1}) was recorded from zero nitrogen with Melkam, which is comparable to 46 with Melkam. Furthermore, Fantaye (2018) noticed that adding 100 kg N ha^{-1} gave rise to the highest biomass production of sorghum (6527 kg ha^{-1}), while unfertilized treatment resulted in the lowest biomass yield (3036 kg ha^{-1}).

Effects of phosphorus fertilizer on sorghum yield and growth characteristics

Yield

Getinet and Atnafu (2022) conducted a field experiment on Nitisols in Kersa District, Southwestern Ethiopia, during the 2017/18 main cropping season to determine the effect of phosphorus fertilizer rates on grain yield and profitable sorghum production. The experiment includes seven P levels (0, 11.5, 23, 34.5, 46, 57.5, and 69 kg ha^{-1} P), one treatment of 46-40 kg ha^{-1} PK to investigate the effect of potassium, and a consistent level of 46 kg N ha^{-1}.

As such, plots treated with (46-40 kg ha^{-1}) PK produced the best grain yield (4517.0 kg ha^{-1}) whereas plots treated with zero phosphorus produced a grain yield that was the least (2212.6 $kgha^{-1}$). According to Ajeigbe *et al.,* (2018), P improved grain yield by 19-39% compared to the control treatment; the maximum mean yield of 3156 kg ha^{-1} at Minjibir and 2929 kg ha^{-1} at BUK suggest optimum yield at the 45 kg P ha^{-1} application rate, respectively. Dereje *et al.,* (2019) conducted experiments to evaluate the reaction of acid soil characteristics and sorghum to lime and phosphorus fertilizer in the Assosa area during the 2012-2015 cropping seasons. The highest sorghum grain yield was obtained with 5.65 t lime ha^{-1} and 46 kg P_2O_5 ha^{-1} treatments, while the lowest grain yield (554.8 kg ha^{-1}) was obtained for the control (no lime or P_2O_5) application.

Plant height and biomass yield

Ajeigbe *et al.,* (2018) studied the influence of phosphorus fertilizer on a predominantly sandy loam soil in two locations within Nigeria's Sudan Savanna Zone during the 2014 and 2015 growing seasons. At Minjibir, they discovered that the application of 45 kg P ha^{-1} brought about the tallest plants (216.5 cm) and the lowest plants (175.6 cm) from the control (0 kg P ha^{-1}).

In BUK, the tallest plants (256.1 cm) were seen when 60 kg P ha^{-1} was utilized, and the shortest plants (230.9 cm) were observed when no P was used. In a comparable manner, the longest plant height (158.05 cm) was obtained from the 38.18 kg P ha^{-1} treatment, but there was no statistically significant difference from 31.50 kg P ha^{-1}; nevertheless, the smallest plant height (129.88 cm) was obtained from the no-fertilizer treatment (Table 3). The application of 46-40 (P-K) kg ha^{-1} resulted in the greatest possible biomass yield (7134.3 kg ha^{-1}), while the control treatment (0 kg P ha^{-1}) resulted in the lowest biomass yield (5366.4 kg ha^{-1}) (Table 2).

Effects of nitrogen and phosphorus fertilizer on sorghum yield and growth characteristics

Yield

According to research conducted in Kenya by Ashiono *et al.,* (2005), the ratio of 40 kg ha^{-1} nitrogen to 30 kg ha^{-1} phosphorus contributed to the highest grain yield of sorghum (9.85 t ha^{-1}). As a result, grain yield increased from 7 to 9 t ha^{-1}, while crude protein content in grain improved by 9.38 to 11.56%. In another investigation carried out by Hailu and Kedir (2022) discovered that 69 kg ha^{-1} of nitrogen and 23 kg ha^{-1} of phosphorus fertilizer gave the highest possible grain yield (4.14 t ha^{-1}), although the control treatment gave the lowest yield (1.37 t ha^{-1}). The highest rate of N/P (69/23 kg ha^{-1}) boosted sorghum grain yield by almost 202.2% when compared with the control treatment. Therefore, for the best grain yield of the sorghum crop in the Kersa district, south-western Ethiopia, N-P at the rate of 69 kg N ha^{-1} and 23 kg N ha^{-1} P_2O_5 is strongly encouraged. According to Sebnie and Mengesha (2018), the highest grain yield (3888.3 kg ha^{-1}) was obtained at a rate of 69/23 N-P_2O_5 kg ha^{-1}, whereas the lowest yield (1698.4 kg ha^{-1}) was obtained with the control treatment.

The highest achievable grain yield of sorghum, 46/23 N - P_2O_5 kg ha^{-1}, was much higher than the lowest rate but was comparable to rates of N-P_2O_5 that reacted linearly of 23/23, 46/23, and 69/23 kg ha^{-1}. Sorghum grain yield increased by 2190.4 kg ha^{-1} and 2148 kg ha^{-1} at 69/23 and 46/23 kg N and P_2O_5 ha^{-1}, respectively, as compared to the control. The yields were raised by 56.33% and 55.88%, respectively.

Desta *et al.*, (2022) carried out on-farm experiments during the 2017 growing season to examine the response of sorghum yield to factorial combinations of nitrogen and phosphorous (NP), as well as potassium (K), sulfur (S), and zinc (Zn), as well as how the location of farmers' fields within various landscape positions (i.e., upslope, mid-slope, and foot-slope) could explain fertilizer response and yield variability. In light of their investigation, they came to the conclusion that fertilizer applications up to 138/69 kg N/P_2O_5 ha^{-1} were the fertilizer rates resulting to the highest grain yield of sorghum. Significant differences in sorghum production were seen after applying 92/46 and 138/69 kg N/P_2O_5 ha^{-1} compared to zero fertilizer treatment, but the yield from 46/23 kg N/P_2O_5 ha^{-1} was equivalent.

The application of K, S, and Zn across all N and P nutrient levels did not, however, result in any appreciable variations in sorghum production. Teshome *et al.*, (2023) also came to the conclusion that omitting N and P decreases the mean agronomic efficiency of those elements. Additionally, these results demonstrated that leaving out K, S, Zn, and B-containing fertilizer had no negative effects on sorghum yield, lower agronomic N and P usage efficiency, or nutrient uptake from the recommended NP.

Plant height and Biomass yield

In line with Sebnie and Mengesha's (2018) report, the fertilizer with the highest plant height in comparison to control was 69 kg ha^{-1} N and 46 kg ha^{-1} Phosphorus. With regard to the control, sorghum's height was longer by 18.21 and 4.33 cm at 69 kg N and 46 kg P_2O_5 ha^{-1}, respectively. However, 69/23 N-P kg ha-1 application produced the largest biomass yield (24924 kg ha^{-1}), while 0 N, 0 P application produced the lowest (8993 kg ha^{-1}). The biomass yield of sorghum is increased by the application of fertilizer by 36.08%.

Effects of organic and inorganic fertilizer on sorghum yield and growth characteristics

Yield and yield components

A number of studies suggested that compost manure rates had an impact on grain yield of sorghum crop. The Federal Polytechnic Bauchi Research and Demonstration Farm conducted a study by Abubakar *et al.*, (2021) aimed at evaluating the impact of compost manure on the development and yield of sorghum (*Sorghum bicolor* L.) during the 2019 rainy season. The treatments consisted of a blanket application of 50 kg ha^{-1} of NPK 15:15:15 fertilizer together with four levels of compost manure (0t ha^{-1}, 2.5 t ha^{-1}, 5.0 t ha^{-1}, and 7.5t ha^{-1}). They found that 7.5 t ha^{-1} of compost produced the best grain yield of sorghum (1238 kg ha-1), while the control (no fertilizer application) yielded the lowest grain yield (554.8 kg ha^{-1}).

The combined use of 45 kg NPK ha^{-1} and 2 tons of cow dung/ha gave the largest amount of grain yield (4.02 t ha^{-1}), while 0 kg N ha^{-1} produced the lowest grain yield (0.70 t ha^{-1}) (Table 4). The grain yield increased when more nitrogen fertilizer was added using cow dung. In the findings of Lasisi and Abdulazeez (2017), the maximum grain yield of 4.4 t ha^{-1} of sorghum was obtained from a treatment that acquired no fertilizer, while the lowest grain yield (1.067 t ha^{-1}) was achieved from a treatment that got no fertilizer in any form. Olani *et al.*, (2004) claim that the application of 30 t ha^{-1} manure and 56 kg P_2O_5 ha^{-1} resulted in greater biomass yields (26.08 t ha^{-1} for Razini and 25.33 t ha^{-1} for Izra-7) that were 53.3 and 60% higher than the control treatment, respectively.

Plant growth attributes

Rani *et al.*, (2018) found that combining 25% RDF + 25% FYM + 25% Flyash + 25% Vermicompost substantially improved plant height, leaf length and number of leaves, stem girth, and plant population of the sorghum crop. As stated by Shuaibu *et al.*, (2018), the interaction of cow dung and NPK fertilizer revealed that the combined application of 45 kg NPK/ha and 2 tons cow dung/ha resulted in the greatest panicle length ($P<0.05$).

Table.1 Influence of different nitrogen rates on growth, yield, and yield components of sorghum

Treatments (kg N ha^{-1})	Plant height (cm)	Panicle length(cm)	Yield/panicle (g)	Thousand seed weight (g)	Grain yield ($kgha^{-1}$)	Stover yield (kg ha^{-1})	Harvest index (%)
0	120.83b	17.03b	54.97b	24.1b	1629.63b	3787.04b	0.30b
50	124.16b	18.46b	58.63b	24.3b	1722.22b	4027.78b	0.30b
100	132.33a	20.93a	75.47a	25.3b	2083.33a	4129.63b	0.34a
150	137.04a	21.25a	75.87a	26.7a	2231.48a	4851.85a	0.32ab
SEM(±)	3.5	0.43	2.05	0.41	51.38	123.25	0.007

Source: Gebrelibanos and Dereje, 2015

Table.2 Effect of phosphorus fertilizer levels on grain yield, biomass yield, and HI of sorghum.

Treatments (kg P ha^{-1})	Grain yield (kg/ha)	Biomass yield (kg/ha)	Harvest index (%)
0	2212.6f	5366.4c	41.2bcd
11.5	2663.2e	6465.7ab	40.0d
23	3148.6d	6425.2ab	41.8cd
34.5	3334.5d	6238.0b	45.4abc
46	3575.5cd	6334.8b	46.5ab
57.5	3965.2bc	6475.1ab	48.0a
69	4091.8ab	6527.9ab	47.2ab
46-40 (P-K)	4517.0a	7134.3a	46.21abc
LSD(0.05)	434.29		4.50

Source: Getinet and Atnafu, 2022

Table.3 Effect of phosphorus fertilization on sorghum yield, plant height, and 1000 seed weight

Treatment	Plant height (cm)	Grain yield Ton/feddan	1000 seed weight (g)
0 kg P	129.88 c	1.59 c	2.11b
29.90 kg P	134.9 b	1.41d	2.13ab
31.50 kg P	157.05a	2.26 a	2.16a
38.18 kg P	158.05 a	1.89 b	2.07c
LSD 5%	1.27	0.85	0.09

Source: Fadol and Eldie, 2022

Table.4 Interaction of NPK fertilizer and cow manure on grain yield and 1000 seed weights of sorghum

Treatments	**Cow dung (t/ha)**						
	0	1	2		0	1	2
	Grain yield(t/ha)				Grain weight (1000 seeds)		
NKP (kg/ha)							
0	0.70^{f}	1.69^{e}	1.73^{e}		20.33^{g}	25.00^{f}	27.67^{e}
15	3.06^{b}	1.74^{e}	1.71^{e}		31.33^{b}	28.67^{d}	29.33^{c}
30	2.39^{d}	2.41^{d}	1.72^{e}		28.67^{d}	32.33^{b}	27.67^{e}
45	2.68^{c}	3.36^{b}	4.02^{a}		29.67^{c}	34.00^{a}	32.67^{a}
LS			*			**	
SE±			0.24			0.89	

Source: Shuaibu *et al.*, (2018). Means followed by the same letter within the same column are not significantly different following DMRT. SE = standard error; * = (P <0.05); ** = (p < 0.01); LS = level of significance.

This illustrated the significance of combining organic and inorganic fertilizer applications in sorghum production. This is consistent with the findings of Gambara *et al.,* (2002), who found that matured cows produced taller plant height, increased the number of leaves per plant, and enhanced sorghum production and yield component.

Sher *et al.*, (2022) studied the effects of organic biochar (BC), sugar industry press mud (MUD), and poultry manure (PM) mixed with inorganic amendments on the yield and nutritional quality of forage sorghum in Pakistan for two years (2019 and 2020). In comparison to the control treatment, the combined application of PM + BC + MUD + 1/2 NPK significantly increased plant height (201 cm), number of leaves (17), stem diameter (18 mm), stem dry weight (201.7 g), leaf dry weight (30.4 g), leaf area (184.3 cm2), green forage yield (31.8 Mg ha^{-1}), and dry biomass yield (12.7 Mg ha^{-1}).

This finding coincides with the findings of Abubakar *et al.*, (2021), who determined that the effects of compost manure on plant height, number of leaves, leaf area index, grain yield, and 1000 grain weight were significant at the P=0.05 level of significance. Compost manure at 7.5 t ha^{-1} yielded significantly greater grain yield (1238 kg ha^{-1}), while the untreated treatment provided the lowest readings.

In general, as observed from the review, all parameters of sorghum are affected by the application of fertilizers. Application of inorganic fertilizers increased the yield and other parameters of sorghum plants above unfertilized treatments. By the same token, the application of organic manures increased the yield and other parameters of sorghum plants over the control treatments. As observed from several findings, N and P fertilizer produced the largest and most significant yield of sorghum, whereas other nutrients had no appreciable effect.

Hence, the combining organic manures and inorganic fertilizer is one of the best options for the environment, saving the farmer costs, improving soil fertility status, and increasing the yield of plants. According to the review, the type of soil, agroecology, and plant variety all influence how plants react to fertilizer. It can be concluded that to maximize the production and productivity of sorghum plants while also improving soil health, it is necessary to set the optimal rate of organic manures and inorganic fertilizer as per the site-specific location.

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