



Role of tillage, organic amendments, and nitrogen in enhancing growth and yield components of maize

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Abstract

*Appropriate tillage and nitrogen management from a suitable source can play a vital role in the optimization of maize (*Zea mays* L.) production. Therefore, the present study was designed with the aim of investigating the effect of tillage, organic matter sources, and nitrogen fertilizer on the growth and yield components of maize. The field experiment was conducted in Agronomy Research Farm, The University of Agriculture, Peshawar, for two consecutive years (2022 and 2023) and was laid out in Randomized Complete Block Design (RCBD) with a split-plot arrangement with three replications. Tillage (deep and shallow) and organic matter sources (Control, Cattle manure, berseem, and wheat straw) were arranged in main plots, and nitrogen fertilizer (urea source) (0, 80, and 120 kg ha⁻¹) was arranged in subplots. Deep tillage plots recorded higher results for grain ear⁻¹, thousand grains weight, biological yield, grain yield, and grain nitrogen content compared to shallow tillage plots. Among organic sources, berseem residue plots improved yield and yield components of maize as compared to other organic matter sources. Plots fertilized by 120 kg N ha⁻¹ increased grain ear⁻¹, thousand grains weight, biological yield, grain yield, and grain nitrogen content as compared to lower levels. Based on experimental results, it was concluded that deep tillage, berseem residue incorporation, and 120 kg ha⁻¹ of nitrogen fertilizer could help farmers increase maize production in the Peshawar valley.*

1. Introduction

Maize, called "Golden food" because of its higher yield and excellent nutritional value (Sahoo *et al.*, 2024; Kumar *et al.*, 2019), is the third most significant crop in Pakistan after rice and wheat and the second most important crop in Khyber Pakhtunkhwa region (Ali *et al.*, 2020). It is commonly cultivated for animals as feed and food and in raw form for use in various industries to make starches, oil, corn syrup and flakes, alcohol, bakers, and wax (Murtaza *et al.*, 2020). Maize contributes significantly to the food supply in most developing countries (Mwambo *et al.*, 2020), and fits well in every cropping system due to higher yield potential, short duration, ability to grow in varying environments, high net

economic, high value for food, forage, and being a cheaper source of feed for livestock, poultry, and many agro-based industries. Pakistan's soil and climate for maize production, but the yield per unit of maize in Pakistan is lower than in many other countries (Khattak *et al.*, 2022). Many reasons justify the low maize yield compared to major producing countries (US, China, Brazil, etc.), such as decreased soil fertility, poor agronomic practices, and limited use of inputs.

Tillage is an effective agricultural activity that improves soil tilth and soil physical conditions (Khan *et al.*, 2024; Khan *et al.*, 2015), which increases the nutrient use efficiency of plants and ultimately leads to increased crop yields (Iqbal *et al.*, 2024; Mishall *et al.*, 2024). Yield and yield components are affected by this field operation due to their effect on the

conservation of water and physico-chemical properties (Zhang *et al.*, 2024; Shaheen *et al.*, 2017). Tillage operation can vary from zero-tillage to deep tillage. In Pakistan, the common tillage practice involves the use of cultivators and rotavators for seedbed preparation. Tillage is a crucial factor that mainly affects the growth and physiological parameters of maize and plays a key role in the management of good soil tilth that ultimately affects crop yield. In many areas, conventional tillage declines crop yield and profitability as compared to deep tillage. Different tillage depths, i.e., deep, conventional or shallow tillage has, i.e., deep, conventional, or shallow tillage, have their own advantages and consequences on the soil. Deep tillage promotes proper residue incorporation and improves collective characteristics related to water, nutrients, heat, and air transport soil (Cai *et al.*, 2014). Among tillage practices, deep tillage improves the yield and yield components of maize (Shoman *et al.*, 2023; Ali *et al.*, 2018). Proper attention is required to adjust different tillage practices with the soil's physical condition for improving yield and yield components.

Organic fertilizer from organic sources represents an alternative to mineral fertilizer to achieve higher maize yield and improve soil environment and soil quality (Zhao *et al.*, 2024; Wang *et al.*, 2017). Researchers described some fertilizers as organic like animal manure, compost, crop residue, oil cakes and biological wastes, rock phosphate, chicken litter, and bone meal (Shi *et al.*, 2024; Khan *et al.*, 2022; Wakawa *et al.*, 2023). Researchers have widely used their application as a better restoration strategy (Qian *et al.*, 2024; Momesso *et al.*, 2022; Luo *et al.*, 2018). The application of organic fertilizers represents a good method of maintaining crop yields (Toishimanov *et al.*, 2023; Manna *et al.*, 2007). Integrated nutrient management is a crucial strategy for maize production, and studies conducted on the combined application of organic and inorganic fertilizers reported considerable maize yield augmentation (Quanquan *et al.*, 2023).

Maize production has significantly increased in the past decades due to the utilization of nitrogenous (N) fertilizer. Nitrogen is the most vital nutrient and major agricultural input throughout the world for maize production by farmers (Sharifi *et al.*, 2024; Gilbert, 2020). It is a major nutrient for plants, which limits their growth if not applied in adequate amounts. Nitrogenous fertilizer has been applied to achieve maximum grain yield. Excessive nitrogen rate will result in excessive vegetative mass of crops (Jug *et al.*, 2018) and increased crop yield (Xu *et al.*, 2020), which will delay grain ripening and prolong vegetation (Wang *et al.*, 2017), increase the sensitivity of crops to diseases and pests, decline in photosynthetic capacity (Hossain *et al.*, 2024; Zhang *et al.*, 2020), and reduce the quality of yield (Bhatt *et al.*, 2024; Yang *et al.*, 2007). Ogola *et al.* (2002) reported that N fertilization increased grain yield by 43 to 68% and biomass

production by 25 to 42%. Many scientists also reported that the utilization of nitrogen enhanced the rate photosynthesis rate, increased leaf area, grain yield; biological yield, and quality of grain (Bhatt *et al.*, 2024; Gul *et al.*, 2021; Zhang *et al.*, 2020). Yield and yield component of maize are largely influenced by tillage practice and nutrient management. However, there are limited published works on integrated nitrogen sources with tillage practices on maize yield from cultivated regions of Pakistan under alkaline calcareous soil and hot climatic conditions. This study's innovation relies on the use of tillage techniques to combine organic and inorganic fertilizers for sustainable agriculture. Therefore, this experiment was conducted to investigate the effect of tillage, organic matter sources, and nitrogen fertilizer on the yield and yield components of maize.

2. Materials and Methods

A field experiment was conducted in an Agronomy research farm (34.1°21' N, 71°28'5'E) at the University of Agriculture Peshawar, Pakistan. The site was situated in sub-tropical zones; the monthly data of rainfall and temperature during both experiment years are given in Table 1. The climate was semiarid and climatic conditions of this area are considered the most suitable for maize-wheat cropping pattern. This arable site has been under an irrigated maize-wheat crop rotation system for over 5 years. The soil of the experimental site was silty loam with sand (29.1 %), silt (55.7 %) and clay (15.2 %), piedmont alluvium and classified as Ustochrept based on USDA classification (SSP, 2007). Before the plantation of maize, soil physicochemical properties from samples taken randomly from a depth of 30cm were measured and documented in Table 2.

2.1. Details of experiment

The experiment was laid out in a randomized complete block da split plot arrangement, and each treatment was repeated three times. The experiment was a three factors study: (a) Type of tillage (T), (b) Organic matter sources, and (c) Nitrogen fertilizer (N). Two levels of tillage (deep and shallow) and four levels of organic matter sources (Control, cattle manure, berseem, and wheat straw) were arranged in main plots, and three levels of nitrogen fertilizer (0, 80, and 120 kg ha⁻¹) were arranged in subplots. Deep tillage was carried out by a mouldboard plow that tilled the soil up to 30 cm, followed by a rotavator. Shallow tillage practice was carried out by the cultivator to a depth of 15 cm, followed by a rotavator. Organic matter sources (cattle manure, berseem, and wheat straw) were applied to relevant plots according to

Table 1: Mean precipitation and air temperature (Maxi and min) during two growing seasons

Months	2022			2023		
	Temp max	Temp min	Rainfall (cm)	Temp max	Temp min	Rainfall (cm)
May	43.7	18.5	19.7	41.0	16.0	27.0
June	45.5	15	59.5	44.0	17.5	49.4
July	41.2	23.2	68	40.5	21.0	90.2
August	39.4	21	56.2	40.0	23.5	4.0
September	38.6	21	5.4	38.6	17.6	33.2
October	36	11	18.4	37.3	12.5	16.0
November	31.5	4.5	51	30.2	6.5	7.7

Table 2: Soil physicochemical properties before sowing of the experimental site

Physico-chemical properties	Units	Soil
Soil total nitrogen content	%	0.06
Soil organic matter	%	0.59
Soil pH	-	8.0
Soil electro conductivity	dSm ⁻¹	0.34
Soil bulk density	g cm ⁻³	1.29

the treatment plan and incorporated into the soil two weeks before the sowing of maize crops at the rate of 5 t ha⁻¹. A calculated amount of nitrogen from urea sources was applied to the field and was incorporated into the soil to get the desired N levels. The amount of N from urea was adjusted to get 80 and 120 kg ha⁻¹ (Table 3). Each experimental unit was 3.75m wide and 5m long, planted with five rows at equal spacing, i.e., 0.75m from each other, and plant-to-plant distance was 25 cm, and sowing was done by a tractor-mounted planter equipped with a row cleaner. The maize cultivar “Azam” was selected for this experiment. Other cultural practices (weeding, thinning, insecticide, herbicides, etc.) were kept uniform for all experimental units.

2.2. Observations and measurements

Five ears from each experimental unit were picked and harvested at physiological maturity. After the threshing, the number of grains ear⁻¹, and the number of grains ear⁻¹ were manually counted from each plot and averaged. At maturity, three central rows in each experimental unit were harvested bundled sun-dried, and sun-dried for ten days. Each bundle was weighed to record biological yield (Equation 1). The harvested material from biological yield was threshed; clean grains were taken and weighed. Data on each experimental unit was taken and converted to grain yield (Equation 2). Data

for biomass and grain yield were used for the harvest index as the ratio of economic yield to biological yield (Equation 3). The grain samples were dried and ground to get powder for nitrogen analysis.

$$\text{Biological yield} = \frac{\text{Biological yield of three rows harvested}}{\text{Row-Row (m)} \times \text{No. of rows harvested} \times \text{Row length(m)}} \times 10000$$

(Equation 1)

$$\text{Grain yield} = \frac{\text{Grain yield of three rows harvested}}{\text{Row-Row (m)} \times \text{No. of rows harvested} \times \text{Row length(m)}} \times 10000$$

(Equation 2)

$$\text{HI (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100 \text{ (Equation 3)}$$

2.3. Data analysis

All collected data were entered into the computer and double-checked before processing. Data were statistically examined using the ANOVA techniques approach recommended for a randomized complete block design with split plot arrangement over the years (Jan et al., 2009), and means between treatments were compared using LSD.

Table 3: Chemical analysis of organic matter sources used in the experiment

Organic sources	Percentage of nitrogen	Rate applied	N from organic matter sources
Cattle manure	1.3 %	5 t ha ⁻¹	6.5 kg ha ⁻¹
Wheat straw	0.5 %	5 t ha ⁻¹	2.5 kg ha ⁻¹
Berseem	1.9 %	5 t ha ⁻¹	9.5 kg ha ⁻¹

3. Results

3.1. Grains ear⁻¹

Tillage, organic matter sources, nitrogen fertilizer, and years, had a significant impact on grains ear⁻¹ (GE) (Table 4). Plots in which deep tillage was applied had a higher GE (375.2) as compared to those with shallow tillage (349.6). Among organic matter sources, plots containing berseem residues recorded the highest GE among organic matter sources (398.1), followed by plots containing cattle manure (376.2), while control plots had the lowest GE (310.2). These results showed that berseem residue incorporation increased GE by 22.1% as compared to control plots. GE was considerably higher after applying 120 kg ha⁻¹ of nitrogen (421.6) than in unfertilized plots (300.0). A 13.3% increase in GE was recorded when nitrogen fertilizer increased from 80 to 120 kg ha⁻¹.

3.2. Thousand grains weight (g)

A statistical investigation of the thousand-grain weight (TGW) of maize showed that tillage practice, organic matter sources, nitrogen fertilizer, and years influenced the TGW of maize (Table 4). Heavier grains were recorded in plots where deep tillage practice was applied (245.7 g) as compared to shallow tillage plots (241.1 g). Comparing organic matter sources, the highest thousand-grain weight was recorded in plots where berseem residue was incorporated (248.9 g), followed by cattle manure plots (246.8 g), while minimum TGW was recorded in control plots (234.6 g). This data showed that berseem residue increased TGW by 5.7% as compared to control plots. TGW increased along all organic matter sources, and higher result was recorded in berseem residue plots. Nitrogen application significantly increased the weight of maize grain. Maximum TGW was recorded in plots fertilized by 120 kg N ha⁻¹ (255.6 g), while minimum TGW was recorded in control plots (227.9 g). Based on this result, increasing nitrogen application from 80 to 120 kg N ha⁻¹ increased TGW by 3.4%.

3.3. Biological yield (kg ha⁻¹)

Biological yield (BY) was significantly affected by tillage, organic matter sources, nitrogen fertilizer, and years (Table 4). In comparison to shallow tillage plots (10521 kg ha⁻¹), deep tillage plots indicated a higher biological yield (10815 kg ha⁻¹). This result showed that deep tillage increased biological yield by 2.8% over shallow tillage.

Among organic sources treatment, maximum BY was recorded in plots where berseem residue was incorporated (11656 kg ha⁻¹), followed by cattle manure plots (11126 kg ha⁻¹), while minimum BY was recorded in control plots (9171 kg ha⁻¹). BY increased along all nitrogen levels applied. Plots fertilized by 120 kg ha⁻¹ significantly increased biological yield (12106 kg ha⁻¹) as compared to unfertilized plots (8681 kg ha⁻¹). The amount of biological yield increased by 6.2% when nitrogen fertilizer increased from 80 to 120 kg ha⁻¹. Biological yield shows significant interaction for organic source and nitrogen levels (Fig. 1). Biological yield showed a greater increase under deep tillage plots as compared to shallow tillage plots, and more increase was recorded when berseem residue was incorporated (Fig. 2).

3.4. Grain yield (kg ha⁻¹)

The grain yield (GY) of maize was strongly impacted by tillage, organic matter sources, nitrogen fertilizer, and years (Table 5). Deep tillage plots (3630 kg ha⁻¹) demonstrated the best results on GY as compared to shallow tillage plots (3418 kg ha⁻¹). This result showed that deep tillage increased GY by 5.8% as compared to shallow tillage. In terms of organic sources data, control plots had the lowest GY (2721 kg ha⁻¹), whereas the berseem residue plots recorded the highest GY (4104 kg ha⁻¹) followed by cow manure plots (3775 kg ha⁻¹). Incorporation of berseem residue improved GY by % compared to control plots sources. Plots fertilized with 120 kg N ha⁻¹ (4127 kg ha⁻¹) recorded higher grain yield of maize, while control plots had the lowest GY (2620 kg ha⁻¹). GY rose by 7.3% when nitrogen fertilizer was increased from 80 to 120 kg N ha⁻¹. Grain yield increased under deep tillage plots as compared to shallow tillage plots, and this increase was more prominent when 120 kg ha⁻¹ of nitrogen was increases from 80 to 120 kg ha⁻¹ (Fig. 4). The interaction between tillage and nitrogen fertilizer showed significant effect on grain yield of maize, deep tillage plots showed maximum grain yield as compared to shallow tillage plots when maximum nitrogen applied (120 kg ha⁻¹) (Fig. 5).

3.5. Harvest index (%)

The Harvest index of maize (HI), is the ratio of grain yield to biological yield and a simple index to easily determine the economic part of the crop. While tillage technique and year were determined to be non-significant,

Table 4: Grain ear⁻¹, thousand grains weight and biological yield of maize as affected by tillage, organic matter, and nitrogen fertilization.

Treatments	Grains ear ⁻¹			Thousand grains weight			Biological yield		
	1 st year	2 nd year	Mean	1 st year	2 nd year	Mean	1 st year	2 nd year	Mean
Type of tillage (T)									
Deep (30 cm)	364.4	385.9	375.2 a	243.0	248.3	245.7 a	10579	11050	10815 a
Shallow (15 cm)	333.6	365.5	349.6 b	238.9	243.3	241.1 b	10331	10712	10521 b
LSD _(0.05)			6.62			1.68			159.85
Organic sources (OS)									
Control	300.7	319.7	310.2 d	233.0	236.3	234.6 d	9153	9190	9171 d
Cattle manure	360.9	391.4	376.2 b	244.4	249.3	246.8 b	10776	11476	11126 b
Berseem	381.5	414.7	398.1 a	246.7	251.2	248.9 a	11397	11915	11656 a
Wheat straw	352.9	377.0	365.0 c	239.7	246.5	243.2 c	10493	10944	10719 c
LSD _(0.05)			9.37			2.37			226.06
Nitrogen (N)									
0	295.5	304.4	300.0 c	225.9	229.8	227.9 c	8534	8541	8537 c
80	352.6	378.4	365.5 b	244.2	249.5	246.8 b	10965	11755	11360 b
120	400.0	444.3	421.6 a	252.8	258.1	255.6 a	11866	12347	12106 a
LSD _(0.05)			7.22			1.72			146.02
Mean of the years	349.0 b	375.7 a	**	240.9 b	245.8 a	*	10455 b	10881 a	**
Interactions	Significance			Significance			Significance		
T x OS	NS			NS			**		
OS x N	**			**			**		
T x N	NS			NS			NS		
T x OS x N	NS			NS			NS		
Y x T	NS			NS			NS		
Y x OS	NS			NS			NS		
Y x N	**			NS			**		
Y x T x OS	NS			NS			NS		
Y x T x N	NS			NS			NS		
Y x OS x N	NS			NS			**		
Y x T x OS x N	NS			NS			NS		
*Significant at p≤0.05				**Significant at p≤0.01			NS Non –significant		

applied (Fig. 3). Grain yield showed a significant increase across all organic sources applied when nitrogen rate organic matter sources and nitrogen fertilizer had a significant impact on maize HI (Table 5). HI was higher in deep tillage plots (32.9%) as compared to shallow tillage pots (32.2%). Among organic sources, plots treated with berseem residue recorded the highest HI (34.8%), followed by plots treated with cattle manure (33.3%), while control plots had the lowest HI (29.7%). Higher harvest index was indicated in plots fertilized by 120 kg N ha⁻¹ (33.8%), while minimum HI was recorded in control plots (30.7%). The interactive effect

of organic sources and nitrogen levels significantly affected the harvest index, as legume residue has the highest harvest index (Fig. 6). The harvest index was significantly affected by type of tillage and nitrogen fertilizer, as the maximum harvest index was recorded in deep tillage cultivated plots as compared to shallow tillage (Fig. 7).

3.6. Grain nitrogen content (%)

While tillage practices and years were found non-significant, organic sources and nitrogen fertilization had a

Table 5: Grain yield, harvest index, and grain nitrogen content of maize as affected by tillage, organic matter, and nitrogen fertilization.

Treatments	Grain yield			Harvest index			Grain nitrogen content		
	1 st year	2 nd year	Mean	1 st year	2 nd year	Mean	1 st year	2 nd year	Mean
Type of tillage (T)									
Deep (30 cm)	3530	3730	3630 a	32.6	33.2	32.9 a	1.46	1.51	1.49
Shallow (15 cm)	3311	3524	3418 b	31.9	32.6	32.2 b	1.43	1.48	1.46
LSD _(0.05)			51.94			0.60			NS
Organic sources (OS)									
Control	2701	2741	2721 d	29.5	29.8	29.7 d	1.22	1.23	1.23 d
Cattle manure	3669	3882	3775 b	33.1	33.5	33.3 b	1.55	1.60	1.57 b
Berseem	3984	4225	4104 a	34.6	34.9	34.8 a	1.58	1.66	1.62 a
Wheat straw	3329	3663	3496 c	31.8	33.3	32.6 c	1.45	1.49	1.47 c
LSD _(0.05)			73.46			0.85			0.04
Nitrogen (N)									
0	2615	2624	2620 c	30.7	30.8	30.7 c	1.11	1.12	1.12 c
80	3683	3968	3825 b	32.8	33.5	33.2 b	1.53	1.61	1.57 b
120	3964	4291	4127 a	33.2	34.4	33.8 a	1.71	1.75	1.73 a
LSD _(0.05)			62.53			0.62			0.03
Mean of the years	3421 b	3627 a	**	32.2 b	32.9 a	NS	1.45	1.49	NS
Interactions									
	Significance			Significance			Significance		
T x OS		**			NS			NS	
OS x N		**			**			**	
T x N		**			**			NS	
T x OS x N		NS			**			NS	
Y x T		NS			NS			NS	
Y x OS		**			NS			NS	
Y x N		**			NS			NS	
Y x T x OS		**			NS			NS	
Y x T x N		NS			NS			NS	
Y x OS x N		NS			NS			NS	
Y x T x OS x N		NS			**			NS	
		NS			NS			NS	
*Significant at $p \leq 0.05$			**Significant at $p \leq 0.01$			NS Non –significant			

substantial impact on grain nitrogen concentration (Table 5). In tillage practices, plots with deep tillage (1.49%) enhanced Grain nitrogen content (GNC) more than those with shallow tillage (1.46%). Regarding organic matter sources, higher GNC was recorded in berseem residues incorporated plots (1.62%), followed by cattle manure plots (1.57%), while lower grain nitrogen content was recorded in control plots (1.23%). GNC was greatly increased by nitrogen treatment; plots fertilized with 120 kg N ha⁻¹ recorded the highest GNC (1.73%), whereas control plots had the lowest (1.12%). Increasing nitrogen application from 80 to 120 kg N ha⁻¹ resulted in a 9.2% rise in GNC. Grain nitrogen content

significantly increased along all organic sources when the fertilizer level increased from 80 to 120 kg ha⁻¹ (Fig. 8).

4. Discussion

Tillage, organic sources, and nitrogen fertilizer significantly influence growth and yield components, and nitrogen fertilizer significantly influences the growth and yield components of maize. The present results are in line with the findings of Ahmad et al. (2021) and Zhou et al. (2020), who revealed that deep tillage increased the GE of maize. The probable reason for higher GE in berseem plots (Table 4)

might be due to the quick breakdown of berseem residue and less lignin, which increases crop nitrogen availability and raises maize grain ear-1 (Khan et al., 2024; Atkins et al., 2007), which increases yield and yield components of maize. Nitrogen application has increased the number of grain ear-1 and this rise in grain ear-1 with maximum nitrogen levels may be the result of less competition for nutrients, which

enables plants to store more biomass and increase their ability to convert more photosynthesis into sink, resulting in more grain ear-1. Sharifi et al. (2024) Adhikari et al. (2021) and Majid et al. (2017) discovered that a higher nitrogen fertilizer resulted in the largest amount of grain per ear, which is comparable to our findings.

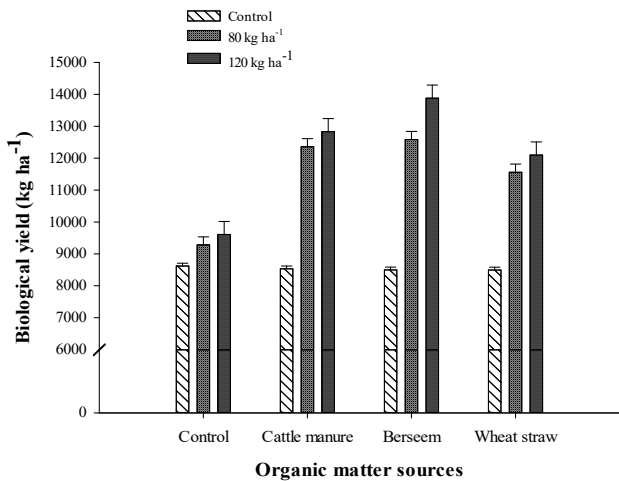


Fig 1. Interaction between organic matter sources (OS) and nitrogen fertilizer (N) for biological yield of maize

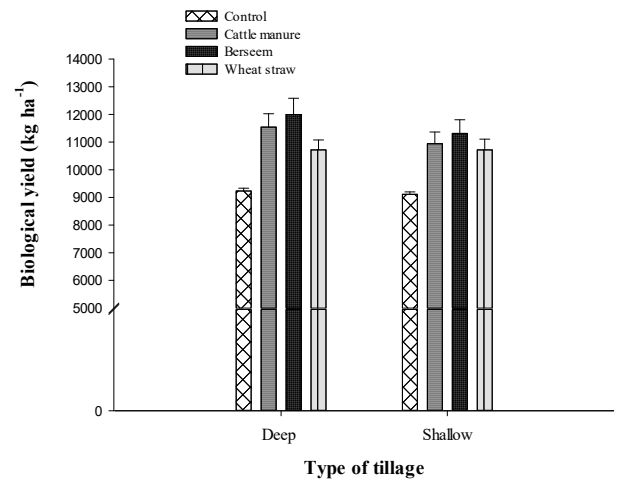


Fig 2. Interaction between type of tillage (T) and organic matter sources (OS) for biological yield of maize

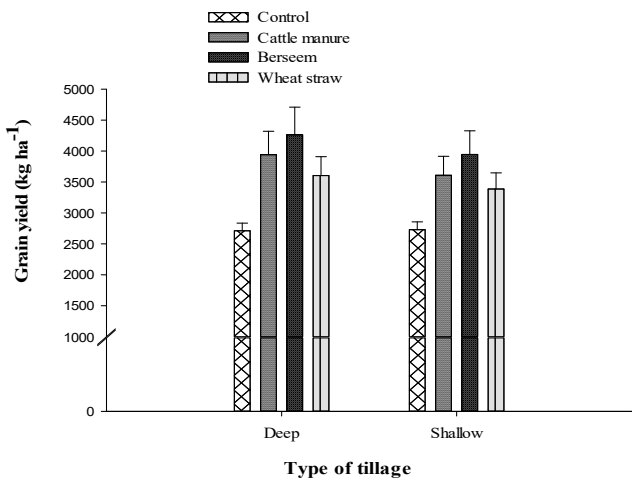


Fig 3. Interaction between type of tillage (T) and organic matter sources (OS) for grain yield of maize

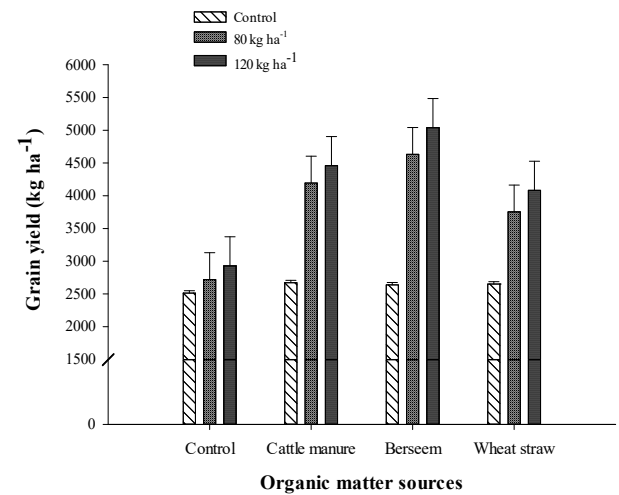


Fig 4. Interaction between organic matter sources (OS) and nitrogen fertilizer (N) for grain yield of maize

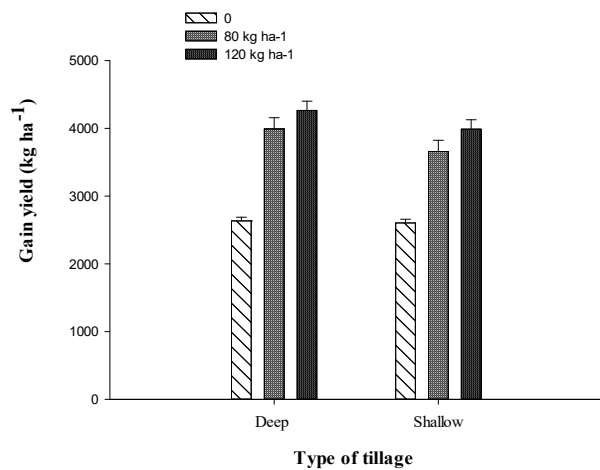


Fig 5. Interaction between type of tillage (T) and nitrogen fertilizer (N) for grain yield of maize

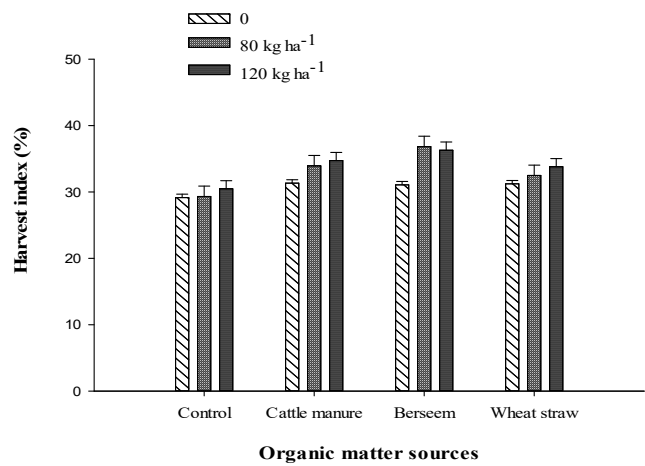


Fig 6. Interaction between organic matter sources (OS) and nitrogen fertilizer (N) for harvest index of maize

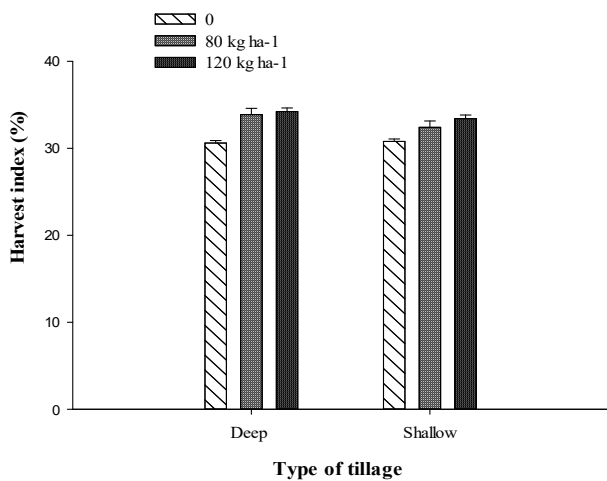


Fig 7. Interaction between type of tillage (T) and nitrogen fertilizer (N) for harvest index of maize

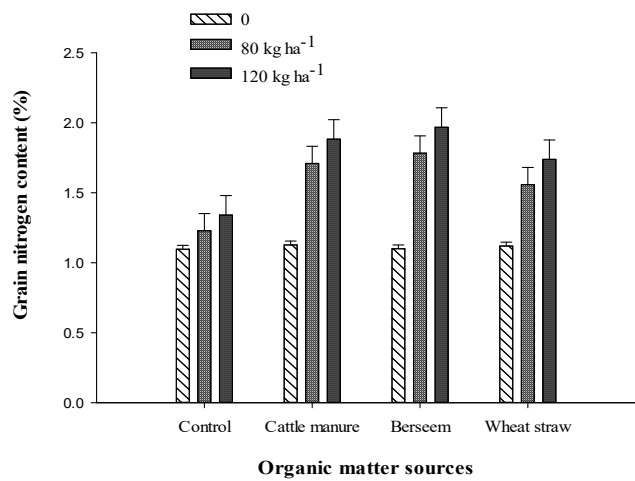


Fig 8. Interaction between organic matter sources (OS) and fertilizer (N) for harvest index of maize

Thousand-grain weights (TGW) is the most significant yield metric (Table 4), which has a direct impact on crop yield and is heavily impacted by fertilization (Khan *et al.*, 2017) and water availability (Ali *et al.*, 2018). By effectively breaking up the hard pan of compacted soil, deep tillage creates a condition that is conducive to improved root growth. Our results are consistent with the results of Ahmad *et al.*, 2021; Khan *et al.* (2017), and Wasaya *et al.* (2012), who reported that 1000-grain weight increased under deep-tilled soils. Regarding nitrogen fertilization, our observations were fully similar to those of Bhatt *et al.*, 2024; Wajid *et al.* (2007),

and Gokmen *et al.* (2001), who found that a greater quantity of photosynthates in grains may be the cause of the rise in 1000 grain weight with increased nitrogen dosage.

The greater biological yield shown in Table 4 under deep tillage might be due to less soil compaction, which improves soil structure, drainage, and aeration (Iqbal *et al.*, 2024; Mishall *et al.*, 2024; Dinnes *et al.*, 2002), soil physical characteristics as well as NO₃⁻ movement. Our results are consistent with the results of Ahmad *et al.* (2021), Khan *et al.* (2017), and Wasaya *et al.* (2012), who reported that deep tillage significantly increased biological yield. Applying

organic matter enhances the physical, chemical, and biological characteristics of the soil, which promotes the breakdown of manure (Luo *et al.*, 2018). This makes nutrients available for better crop growth and, consequently, biological output. Our findings were comparable to those of Sharifi *et al.* (2024), Adhikari *et al.* (2021), and Hammad *et al.* (2011) who indicated that the highest biological yield was observed with higher nitrogen doses.

The higher grain yield achieved under deep tillage (Table 5) could be due to better soil tilth and edaphic conditions for SOC decomposition and mineralization, which raise the availability of plant nutrients and may justify the higher grain yield attained from deep tillage (Mishall *et al.*, 2024 and Ahmad *et al.*, 2021). The deeper penetration has loosened soil aggregates and created channels for water transmission into the crop rhizosphere. Our results were similar to those of Zhang *et al.* (2024) and Shahid *et al.* (2016) who reported that deep tillage resulted in higher grain yield. Higher nitrogen levels may boost grain yield because there is less competition for nutrients, resulting in a larger plant canopy and more photosynthetic activity, which allows the bold grain to acquire more biomass. Our outcomes were similar to those of Mishall *et al.*, 2024; Gul *et al.* (2021); Shrestha *et al.* (2018), and Sharifi and Namvar (2016), who found that applying a high dose of N produced the highest grain yield.

The Harvest index of maize is the ratio of grain yield to biological yield, and a simple index to easily determine the economic part (Table 5). Deep tillage significantly improved the harvest index. This rise may have been caused by the use of deep tillage, which speeds up the breakdown of organic sources in soil that is far away from the rhizosphere and releases nutrients into the root zone (Iqbal *et al.*, 2024, Anikwe *et al.*, 2007). Our results agreed with those of Mishall *et al.*, 2024; Sharifi and Namvar (2016), and Wajid *et al.* (2007) who found the maximum harvest index with the application of a higher nitrogen dose.

Deep tillage reduces soil compaction, improves soil physical properties, therefore improves soil physical properties, and, therefore, leads to higher maize grain nitrogen content (Khan *et al.*, 2024 Wang *et al.*, 2015). The nitrogen content in grain increased as the nitrogen supply increased (Table 5). Our results are similar to those of Gul *et al.* (2021) and Kaplan *et al.* (2019), who reported that increased N fertilizer increased grain nitrogen content. It was obvious that higher fertilizer rates expressed a positive impact on grain nitrogen content.

5. Conclusion

Tillage is an important factor that plays a significant role in crop productivity and availability of nutrients. It affects the yield and yield components of maize and deep tillage enhances the availability of nutrients to the plants. Besides, berseem residue improved more yield and yield components

of maize compared to other organic sources. It also enhances the quality of soil for plant productivity and grain quality. Furthermore, a nitrogen rate of 120 kg ha⁻¹ improved yield and yield components of maize, which in turn led to higher grain nitrogen content. From this study, it is recommended that deep tillage, berseem residue incorporation, and 120 kg N ha⁻¹ improved yield and yield components of maize in Peshawar. A future research direction could focus on exploring the impact of these practices on maize resilience to climate change, especially under drought or extreme weather events.

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8. Conflict of Interest

The authors declare no conflict of interest.

9. Authors' Contribution

KOSSOKO Adeola Abdel Djalal, and Asim Muhammad: Planned and designed the research. KOSSOKO Adeola Abdel Djalal: Conducted the fieldwork, collected data and analysed. Asim Muhammad: Conducted the supervision on the field, provided guidance throughout the research process, and reviewed the manuscript. Lastly, the final draft was reviewed and approved by all authors.

References

- Adhikari, K., Bhandari, S., Aryal, K., Mahato, M., & Shrestha, J. (2021). Effect of different levels of nitrogen on growth and yield of hybrid maize (*Zea mays* L.) varieties. *Journal of Agriculture and Natural Resources*, 4(2), 48–62.
- Ahmad, H., Shafi, M., Liaqat, W., Jan, M. F., Ahmad, S., & Farooq, M. (2021). Maize yield as affected by methods of tillage and weed management. *Indian Journal of Weed Science*, 54(1), 51–57. <https://doi.org/10.28941/pjwsr.v27i1.892>
- Ali, A., Beshir Issa, A., & Rahut, D. B. (2020). Adoption and impact of the maize hybrid on the livelihood of the maize growers: Some policy insights from Pakistan. *Scientifica*, 2020, 5959868. <https://doi.org/10.1155/2020/5959868>
- Ali, A., Usman, M., & Adaikwu, A. O. (2018). Effect of tillage methods on soil properties, growth, and yield

- of maize (*Zea mays* L.) in Makurdi, Nigeria. *International Journal of Science and Healthcare Research*, 3(1), 48–55.
- Atkinson, B. S., Sparkes, D. L., & Mooney, S. J. (2007). Using selected soil physical properties of seedbeds to predict crop establishment. *Soil and Tillage Research*, 97(2), 218–228. <https://doi.org/10.1016/j.still.2007.09.017>
- Bhatt, S., & Ghimire, S. (2024). Quantifying the impact of nitrogen levels on spring maize varieties (*Zea mays* L.) in Kanchanpur, Nepal. *Innovations in Agriculture*, 7, 1–10. <https://doi.org/10.3897/ia.2024.124217>
- Bayoh, F., George, M. S., Kassoh, F. A., & Bah, A. M. (2024). Response of maize grain yield to different sources of organic manure at varied levels of application. *African Journal of Agricultural Research*, 20(1), 113–122. <https://doi.org/10.5897/AJAR2023.16537>
- Cai, H., Ma, W., Zhang, X., Ping, J., Yan, X., Liu, J., & Ren, J. (2014). Effect of subsoil tillage depth on nutrient accumulation, root distribution, and grain yield in spring maize. *Crop Journal*, 2(5), 297–307. <https://doi.org/10.1016/j.cj.2014.04.006>
- Gul, H., Rahman, S., Shahzad, A., Gul, S., Qian, M., Xiao, Q., & Liu, Z. (2021). Maize (*Zea mays* L.) productivity in response to nitrogen management in Pakistan. *American Journal of Plant Sciences*, 12(8), 1173–1179. <https://doi.org/10.4236/ajps.2021.128081>
- Hammad, H. M., Ahmad, A., Azhar, F., Khaliq, T., Wajid, A., Nasim, W., & Farhad, W. (2011). Optimizing water and nitrogen requirement in maize (*Zea mays* L.) under semi-arid conditions of Pakistan. *Pakistan Journal of Botany*, 43(6), 2919–2923.
- Hossain, S., Al-Solaimani, S. G., Alghabari, F., Shahzad, K., & Rashid, M. I. (2024). Enhancing maize yield through sustainable and eco-friendly practices: The impact of municipal organic waste compost and soil amendments. *Cogent Food & Agriculture*, 10(1), 2307119.
- Imran. (2024). Integration of organic, inorganic, and bio fertilizer improves maize-wheat system productivity and soil nutrients. *Journal of Plant Nutrition*, 1–17. <https://doi.org/10.1080/01904167.2024.2354190>
- Iqbal, J., Khaliq, T., Ahmad, A., Khan, K. S., Haider, M. A., Ali, M. M., & Rehmani, M. I. A. (2024). Productivity, profitability, and energy use efficiency of wheat-maize cropping under different tillage systems. *Farming Systems*, 2(3), 100085. <https://doi.org/10.1016/j.farsys.2024.100085>
- Jan, S. L., Shah, P., Hollington, P. A., Khan, M. J., & Sohail, Q. (2009). *Agriculture research: Design and analysis: A monograph*. Department of Agronomy, The University of Agriculture, Peshawar, 85–91.
- Jug, D., Jug, I., Brozović, B., Vukadinović, V., Stipešević, B., & Đurđević, B. (2018). The role of conservation agriculture in mitigation and adaptation to climate change. *Poljoprivreda*, 24(1), 35–44. <http://dx.doi.org/10.18047/poljo.24.1.5>
- Kaplan, M., Karaman, K., Kardes, Y. M., & Kale, H. (2019). Phytic acid content and starch properties of maize (*Zea mays* L.): Effects of irrigation process and nitrogen fertilizer. *Food Chemistry*, 283, 375–380. <https://doi.org/10.1016/j.foodchem.2019.01.029>
- Khattak, M. K., Hanif, M., Jaddon, S. A., Haq, I. U., & Uddin, R. (2022). Phenological and yield components response of major exotic maize varieties to different levels of soil bulk densities. *SAINS TANAH: Journal of Soil Science and Agroclimatology*, 19(2), 160–164. <https://dx.doi.org/10.20961/stjssa.v19i2.59>
- Khan, H., Khan, A., Khan, S., Anjum, A., Akbar, H., & Muhammad, D. (2024). Maize productivity and nutrient status in response to crop residue mineralization with beneficial microbes under various tillage practices. *Soil and Tillage Research*, 239, 106057. <https://doi.org/10.1016/j.still.2024.106057>
- Khan, I., Zada, S., Rafiq, M., Sajjad, W., Zaman, S., & Hasan, F. (2022). Phosphate solubilizing epilithic and endolithic bacteria isolated from clastic sedimentary rocks, Murree lower Himalaya, Pakistan. *Archives of Microbiology*, 204(6), 332. <https://doi.org/10.1007/s00203-022-02946-2>
- Here is the corrected APA 7th edition reference list with full journal names:
- Khan Shahbaz, S. K., Aqeel Shah, A. S., Muhammad Nawaz, M. N., & Mohsin Khan, M. K. (2017). Impact of different tillage practices on soil physical properties, nitrate leaching and yield attributes of maize (*Zea mays* L.). *Journal of Soil Science and Plant Nutrition*, 17(1), 240–252.
- Khan, A., Jan, M. T., Afzal, M., Muhammad, I., Jan, A., & Shah, Z. (2015). An integrated approach using organic amendments under a range of tillage practices to improve wheat productivity in a cereal-based cropping system. *International Journal of Agriculture and Biology*, 17(3), 467–474. <https://doi.org/10.17957/IJAB/17.3.13.248>
- Kumar, M., Singh, S., Singh, V., Singh, K., & Khanna, R. (2019). Effect of zinc and boron application on growth and yield of maize (*Zea mays* L.). *Progressive Agriculture*.
- Luo, G., Li, L., Friman, V. P., Guo, J., Guo, S., Shen, Q., & Ling, N. (2018). Organic amendments increase crop

- yields by improving microbe-mediated soil functioning of agroecosystems: A meta-analysis. *Soil Biology and Biochemistry*, 124, 105–115. <https://doi.org/10.1016/j.soilbio.2018.06.002>
- Majid, M. A., Islam, M. S., El-Sabagh, A., Hasan, M. K., Saddam, M. O., Barutcular, C., & Islam, M. S. (2017). Influence of varying nitrogen levels on growth, yield and nitrogen use efficiency of hybrid maize (*Zea mays* L.). *Journal of Experimental Biology and Agricultural Sciences*, 5(2), 134–142. [https://doi.org/10.18006/2017.5\(2\).134.142](https://doi.org/10.18006/2017.5(2).134.142)
- Manna, M. C., Swarup, A., Wanjari, R. H., Mishra, B., & Shahi, D. K. (2007). Long-term fertilization, manure and liming effects on soil organic matter and crop yields. *Soil and Tillage Research*, 94(2), 397–409. <https://doi.org/10.1016/j.still.2006.08.013>
- Momesso, L., Crusciol, C. A. C., Cantarella, H., Tanaka, K. S., Kowalchuk, G. A., & Kuramae, E. E. (2022). Optimizing cover crop and fertilizer timing for high maize yield and nitrogen cycle control. *Geoderma*, 405, 115423. <https://doi.org/10.1016/j.geoderma.2021.115423>
- Murtaza Ali, S., Shah, S., Ahmad, M., Ullah, I., & Khan, J. (2020). Adoption of hybrid maize technology in district Mardan of Khyber Pakhtunkhwa, Pakistan. *Sarhad Journal of Agriculture*, 36(4), 1047–1053. <https://doi.org/10.17582/journal.sja/2020/36.4.1047.1053>
- Mwambo, F. M., Fürst, C., Nyarko, B. K., Borgemeister, C., & Martius, C. (2020). Maize production and environmental costs: Resource evaluation and strategic land use planning for food security in northern Ghana by means of coupled emergy and data envelopment analysis. *Land Use Policy*, 95, 104490. <https://doi.org/10.1016/j.landusepol.2020.104490>
- Mishall, A. (2024). Soil compaction induced by different tillage systems and its impact on growth and yield of maize (*Zea mays* L.): A review. *University of Thi-Qar Journal of Agricultural Research*, 13(1), 185–200. <https://doi.org/10.54174/szm42027>
- Ogola, J. B. O., Wheeler, T. R., & Harris, P. M. (2002). Effects of nitrogen and irrigation on water use of maize crops. *Field Crops Research*, 78(2–3), 105–117. [https://doi.org/10.1016/S0378-4290\(02\)00116-8](https://doi.org/10.1016/S0378-4290(02)00116-8)
- Qian, R., Ma, Z., Yang, Y., Guo, R., Han, F., Wang, J., & Jia, Z. (2024). Optimizing maize productivity: A sustainable approach integrating straw derivatives and film mulching in rainfed agriculture. *Field Crops Research*, 307, 109268. <https://doi.org/10.1016/j.fcr.2024.109268>
- Sahoo, S., Seleiman, M. F., Roy, D. K., Ranjan, S., Sow, S., Jat, R. K., & Gitari, H. (2024). Conservation agriculture and weed management effects on weed community and crop productivity of a rice-maize rotation. *Heliyon*, 10(10). <https://doi.org/10.1016/j.heliyon.2024.e31554>
- Sharifi, R. S., & Namvar, A. (2016). Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (*Zea mays* L.). *Biologija*, 62(1), 35–45.
- Shi, C., Zhang, Q., & Yu, B. (2024). Higher improvement in soil health by animal-sourced than plant-sourced organic materials through optimized substitution. *Agriculture, Ecosystems & Environment*, 363, 108875. <https://doi.org/10.1016/j.agee.2023.108875>
- Shoman, H. A. (2023). Effect of tillage systems and organic fertilizers on maize (*Zea mays* L.) productivity in alkaline soils. *Egyptian Journal of Desert Research*, 73(2), 679–694.
- Toishimanov, M., Suleimenova, Z., Myrzabayeva, N., Dossimova, Z., Shokan, A., Kenenbayev, S., & Serikbayeva, A. (2023). Effects of organic fertilizers on the quality, yield, and fatty acids of maize and soybean in Southeast Kazakhstan. *Sustainability*, 16(1), 162. <https://doi.org/10.3390/su16010162>
- Wasaya, A., Tahir, M., Tanveer, A., & Yaseen, M. (2012). Response of maize to tillage and nitrogen management. *Journal of Animal and Plant Sciences*, 22(2), 452–456.
- Wajid, A., Ghaffar, A., Maqsood, M., Hussain, K., & Nasim, W. (2007). Yield response of maize hybrids to varying nitrogen rates. *Pakistan Journal of Agricultural Sciences*, 44(2), 217–220.
- Wang, X., Ren, Y., Zhang, S., Chen, Y., & Wang, N. (2017). Applications of organic manure increased maize (*Zea mays* L.) yield and water productivity in a semi-arid region. *Agricultural Water Management*, 187, 88–98. <https://doi.org/10.1016/j.agwat.2017.03.017>
- Yang, J. Y., Huffman, E. C., De Jong, R., Kirkwood, V., MacDonald, K. B., & Drury, C. F. (2007). Residual soil nitrogen in soil landscapes of Canada as affected by land use practices and agricultural policy scenarios. *Land Use Policy*, 24(1), 89–99. <https://doi.org/10.1016/j.landusepol.2006.03.002>
- Zhang, Y., Zhang, Y., Gao, Y., McLaughlin, N. B., Huang, D., Wang, Y., & Liang, A. (2024). Effects of tillage practices on environment, energy, and economy of maize production in Northeast China. *Agricultural Systems*, 215, 103872. <https://doi.org/10.1016/j.agry.2024.103872>

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