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Growth and Phenology of Hybrid Maize as Influenced by Different Levels of Nitrogen and Plant Population

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Abstract

Agronomic measurements like proper planting geometry and fertilizer application increase physiological characteristics and ultimately the grain yield of maize. The experiment was laid out in a split-plot design with three replications consisting of four levels of nitrogen (0, 70, 140 and 210 kg/ha^{-1}) as the main plot factor, and four levels of the population (55,555, 69,444, 85,470 and 1,01,010 plants ha^{-1}) as subplot factor in the humid sub-tropical condition of Chitwan, Nepal. Different levels of nitrogen and plant population did not significantly affect the number of days to emergence (VE), appearance of knee high (V6), milking and daugh stage of hybrid maize. However, the timing of tasseling and silking in winter maize hybrid crops was notably influenced by plant population levels. Higher level of nitrogen 210kgNha^{-1} significantly delayed physiological maturity as compared to the control. The height of plants recorded at harvest with the application of 210 kgNha^{-1} and 140 kgNha^{-1} were similar to each other, but significantly taller than the control at 30 to 90DAS of hybrid maize. Similarly, Plant height remained largely unaffected by varying plant populations during most growth stages, except at the pre-milking stage (90DAS), where a higher density of 101 thousand plants ha^{-1} (192.5cm) significantly increased height compared to 55 (163.0 cm) and 69 (165.0cm) thousand plants ha-1. The values of the total dry matter accumulated in maize plants with 70,140 & 210kgNha^{-1} at 75, 120 & 150 DAS were significantly higher in comparison to the control. Similarly, the total dry matter accumulated in maize plants were significantly higher with 101 thousand plants ha^{-1} in comparison to 69 and 55 thousand plants ha^{-1}, but remained at par with 85 thousand plants ha^{-1} at silking (75DAS) and physiological maturity

(150DAS) stages. the values of LAI obtained with the application of 140kgNha^{-1} were significantly higher as compared to 210, 70 and 0 kgNha^{-1} which remained at par with 210 and 70kgNha^{-1} except in 45 (after the knee-high stage) &60 (before tasselling stage) DAS and 90 (after silking stage) & 105 (before milking stage) DAS, respectively. Contrastingly, plant population levels did not significantly impact leaf area index in this experiment, except at 60DAS.

Keywords: *Maize, nitrogen, plant population, growth stages*

Introduction

Maize, or *Zea mays*, a vital grain crop crucial for global food security, is profoundly influenced in growth and yield by key factors such as nitrogen availability and plant population. As a member of the Poaceae family of grasses, maize is one of the most extensively grown and commercially significant crops in the world. It is one of the most significant grains, cultivated in a variety of climates and regions for human consumption, animal feed and fodder, and industrial raw materials (Jeet et al., 2012). When it comes to both acreage and production, maize is regarded as Nepal's second most significant staple crop, behind rice (ABPSD, 2015). In 2020, the total area under maize was 9, 57,650 ha with a production of 28.35,674 MT and productivity of 2.96 MT/ha (MOAD, 2020). Maize crop alone contributes about 25.02% of total cereal production, 6.88% in Agriculture's Gross Domestic Product (AGDP) and 3.15% in Gross Domestic Product (Pandey & Basnet, 2018). The rapidly increasing demand for maize grain is related to its greater demand for direct human consumption in the hills as a staple food crop (Ghimire et al., 2007), and for livestock feeds in terai and inner terai areas (Pandey, Adhikari& Sharma, 2007). The crop is mostly grown under rainfed conditions during the summer (April- August) as a sole crop or relayed with millet later in the season in Nepal. In the winter and spring seasons, it is grown in the terai, inner terai and low-lying river basin areas with partial irrigation (Paudyal et al., 2001).

Nitrogen (a vital plant nutrient) is an important factor for maize production (Jeet et al., 2012) and productivity and its availability in sufficient quantity throughout the growing season is essential (Habtegebrial, Singh & Haile, 2007). Nitrogen fertilization plays a significant role in improving soil fertility and increasing crop productivity. Nitrogen affects various physiological and biochemical processes in plant cells that ultimately affect the growth and development of the plant. Nitrogen response by maize differs due to growth stages, environment and genotype of maize. The higher nitrogen fertilizer increases vegetative growth by enhancing leaf initiation, increments chlorophyll concentration in leaves that improving photosynthesis (Mekded, 2015). With the use of nitrogen grain yield can be increased by (43-68%) and biomass (25- 42%) in maize (Ogola et al., 2002). Chemical fertilizer application particularly nitrogen could not be avoided completely since they are the potential sources of high amounts of nutrients in easily available forms and maize is more responsive to it (Obi et al., 1995). The spacing between maize plants during planting, commonly referred to as plant spacing, is a critical factor that influences the overall yield and growth of the crop. Plant density is one of the most important cultural practices determining grain yield, as well as other important agronomic attributes of this crop. Maize is generally grown in wide-spaced rows. The ways that maize responded to plant density varied widely (Laque et al., 2006) and increased competition among plants for light, space, water, nutrients, and other growing factors results from a greater population, which affects the crop yield (Sangoi et al., 2002). Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partition (CASAL, 1985). Agronomic measurements like proper planting geometry (Maddonni et al., 2001) and fertilizer application (Rasheed et al., 2004) increased physiological characteristics and consequently the grain yield (Inamullah et al., 2011). Farmers are still uncertain about the correct selection of various factors such as nitrogen levels and plant population for the cultivation of hybrid maize. Keeping in view the importance of plant density and nitrogen, the study was conducted to find out optimum plant population and appropriate level of nitrogen for better performance of hybrid maize. Most of the growth parameters of maize can be affected by plant population even in optimal growing conditions.

Materials and Methods

The study was conducted at the National Maize Research Program (NMRP), Rampur, Chitwan, spanning from September to March, utilizing the maize hybrid (RML95/RML96). Employing a split-plot design with three replications, the main plot factor included four plant population levels (55,555, 69,444, 85,470, and 1,01,010 plants ha-1), while the sub-plot factor comprised four nitrogen levels (0, 70, 140, and 210 kg Nha-1). Half of the nitrogen, along with full doses of phosphorus and potash, was applied at sowing, while the remaining nitrogen was split at the V6 (knee-high) and V8 (Tasseling) stages. The final plant stand was maintained at the V6 growth stage, with plant-to-plant distances of 30, 24, 19.5, and 16.5 cm for populations of 55, 69, 85, and 101 thousand plants ha-1, respectively, and a constant row-to-row distance of 60 cm. Fertilizers used included Urea, SSP, and MoP. Table 1 justify the experimental field's soil was slightly acidic with a pH of 6.1, very low organic matter (1.83), and varying levels of total nitrogen, available phosphorus, and available potassium. Growth attributes and phenological data were recorded at 15-day intervals from germination, and data analysis employed Excel, Gen-Stat, & M-Stat C. Means were compared using an LSD test at 0.05 level of probability, if the F-values are significant.

Table 1

Physio-chemical Characteristics of the Soil (0-15 cm) of the Experimental Site, NMRP, Rampur

S.N.	Properties	Average content	Rating	Reference
1.	Physical properties			
	Sand (%)	65.0		Hydrometer method
	Silt (%)	12.5		
	Clay (%)	9.0		
2.	Textural class /Rating		Sandy loam	
3.	Chemical properties			
	Soil pH	6.1	Slightly Acidic	Beckman Glass electrode pH meter (Pradhan, 2005)
	Soil organic matter (%)	1.83	Low	Walkey and Black method (Walkey & Black, 1934)
	Total nitrogen (%)	0.09	Very Low	Kjeldahl distillation unit (Jackson, 1967)
	Available phosphorus (kg ha $^{-1}$)	208.39	Very High	Spectrophotometer (Olsen, Cole & Dean, 1954)
	Available potassium (kg ha $^{-1}$)	228.22	Medium	Ammonium acetate method (Black et.al., 1965)

Results and Discussion

Table 2

Phenological Stages (in days) of Hybrid Maize as Influenced by Nitrogen and Plant Population

Treatments	Germination	Knee-high	Tasseling	Silking	Milking	Dough	Physiological maturity
Nitrogen rate kg ha^{-1}							
0	5.75	36.67	70.33	73.67	121.83	132.17	146.42 ^{b}
70	5.58	36.50	67.75	70.83	122.50	132.72	147.83^{ab}
140	5.91	36.17	69.17	72.42	122.83	133.17	147.83^{ab}
210	5.75	36.33	69.58	72.83	123.67	133.58	149.17^{a}
SEm (±)	0.18	0.28	1.68	1.56	0.65	0.84	0.801
$LSD_{0.05}$	Ns	Ns	Ns	Ns	Ns	ns	2.339
Plant population ha^{-1}							
55,555	5.91	36.25	65.50^{c}	69.25^{b}	121.33	132.42	147.08
69,444	5.58	36.00	68.08^{bc}	70.92^{b}	122.42	133.00	148.03
85,470	5.50	36.00	73.25^{a}	76.33^{a}	123.42	133.25	148.38
101010	6.00	37.42	70.00^{ab}	73.25^{ab}	123.67	134.58	147.25

SEm (±)	0.13	0.61	1.19	1.29	1.27	0.99	1.077
$LSD_{0.05}$	Ns	Ns	4.14	4.47	ns	ns	ns
CV %	10.90	2.70	8.40	7.50	1.80	2.20	1.90
Grand mean	5.75	36.42	69.21	72.44	122.71	133.06	147.81

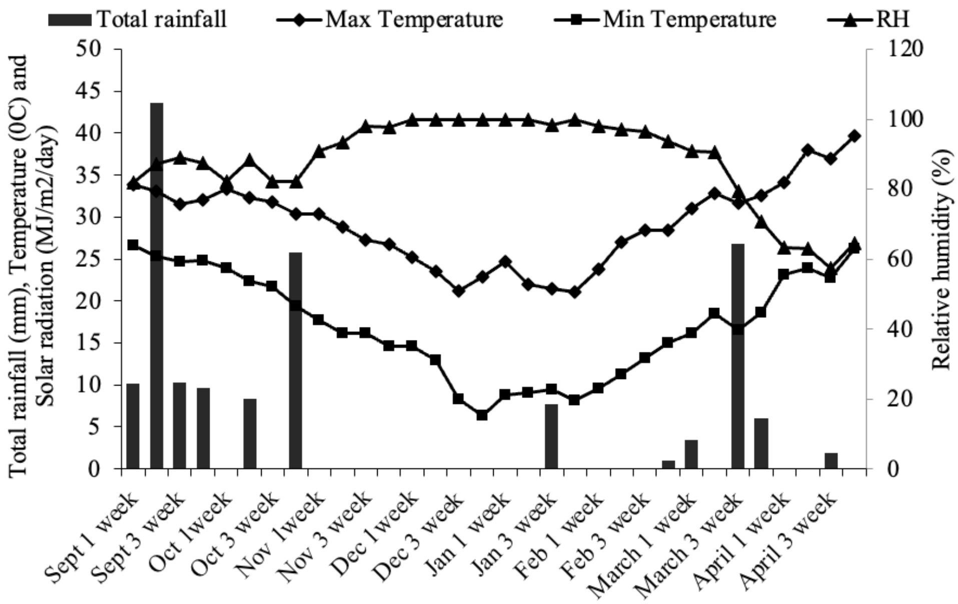
Different levels of nitrogen and plant population did not significantly affect the number of days to emergence. This could be attributed to respective pre-sowing rainfall of 43.60 mm, 10.3 mm, and 9.6 mm in the third, second, and first weeks (figure 1) , as germination relies on moisture, temperature, and oxygen (Wajid, et al., 2007). Furthermore, the recorded temperatures at sowing (32.84°C max, 23.13°C min) (figure 1) were conducive for germination, possibly aided by ample cotyledon food reserves for initial plant growth. (Belfield & Brown, 2008). Similarly, during primary growth stages plants use residual soil inorganic (Brady & Weil, 2010).

On the other hand, the timing of tasseling and silking in winter maize hybrid crops was notably influenced by plant population levels, with a significant delay observed at 85 thousand plants ha^{-1} compared to 69 and 55 thousand plants ha^{-1}. In this context, Hammad and Nasab (2001) also reported that plots maintained at high density (100,000 plants ha^{-1}) took slightly more duration to tasseling and silking than the plots maintained at low density (60,000 plants ha^{-1}). This implies that planting at a high density may have slightly hindered the pace of plant development due to increased competition within the dense population (Hamid and Nasab, 2001).

More nitrogen leads to increased thermal time for tasseling, silking, and physiological maturity in maize, and vice versa. Additionally, a higher nitrogen rate may enhance photosynthesis, leading to prolonged leaf durability and delayed phenological characteristics in the crop (Gungula, et al., 2003). Delay in reaching physiological maturity at higher levels may be attributed to prolonged greenness, delayed leaf senescence, and increased nitrogen content in the leaves, consequently leading to delayed leaf drying (Shrestha, 2013). Further, the result of the experiment showed that days to physiological maturity stage was not influenced significantly by the levels of plant population however it was earlier in the treatment with 55 than 69 and 85 thousand plants ha^{-1}. Consistent with Dawadi & Sah, 2012, the time required for hybrid maize varieties to reach physiological maturity in winter was not significantly influenced by plant population levels ranging from 55 to 83 thousand plants ha^{-1}

Figure 1

Weather Condition During the Course of Experimentation at NMRP, Rampur, Chitwan, Nepal



Plant height of hybrid maize influenced by different levels of nitrogen and plant population (Figure 2 and 3).

Figure 2

Plant Height of Maize as Influenced by Nitrogen

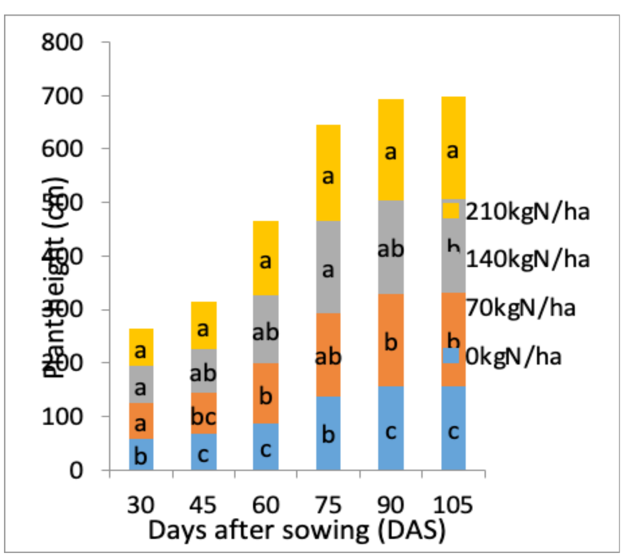
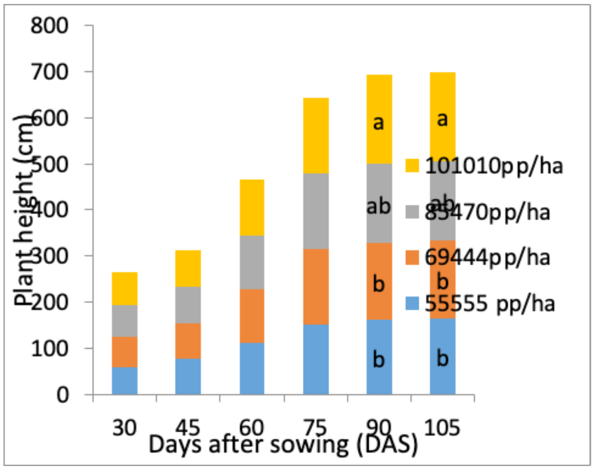


Figure 3

Plant Height of Maize as Influenced by Plant Population



The height of plants recorded with the application of 210kgNha^{-1} and 140 kgNha^{-1} were similar to each other but significantly taller than control without nitrogen at almost all growth stages from 30 to 90 DAS of hybrid maize. Moreover, significant differences were recorded between the maximum (210 kgNha^{-1}) and minimum (70kgNha^{-1}) nitrogen rates before tasseling (60DAS) and milking stage (90DAS) in respect of plant height. At 105DAS (prior to the milking stage) the plant height measured in the treatment with 210kgNha^{-1} (176.5 cm) and 70 (173.6 cm) was significantly higher than 140 kg Nha^{-1}but, were similar to each other (Figure 2).

This could be attributed to the fact that employing higher doses of nitrogen promotes cell division, cell elongation, nucleus formation, and the development of green foliage. Additionally, it stimulates the growth of shoots. Consequently, greater nitrogen dosages raise the amount of chlorophyll, which in turn raises the rate of photosynthesis and stem elongation, increasing plant height (Mahesh et al., 2016, Shapiro and Wortmann, 2006).

Similarly, plant height in hybrid maize was generally unaffected by various plant populations at most growth stages. However, at the pre-milking stage (90DAS), a higher plant population of 101 thousand plants ha-1 (192.5cm) significantly increased height compared to 55 (163.0cm) and 69 (165.0cm) thousand plants ha^{-1} but was similar to 85 (172.6cm) thousand plants ha^{-1}, which were also comparable to each other. (Figure 3). Plant height increases with the increase in plant population due to competition for light (Reddy & Reddi, 2002; Bisht et al., 2012). On the other hand, it decreases with the increase in plant population due to competition for water and nutrients (Reddy & Reddi, 2002). Thus, a higher plant population increases stress and competition for nutrients, sunlight and water (Adeniyan, 2014). Moreover, under higher plant population the crop net photosynthesis process is affected due to less light penetration in the crop canopy as well as due to increase in competition for available nutrients which affects crop growth (Azam et al., 2007).

The values of the total dry matter accumulated in maize plants in control without nitrogen were significantly lower in comparison to 70,140 & 210kgNha^{-1} at 75, 120 & 150 DAS. Maintaining nitrogen uptake during silking is crucial in maize to minimize the need for nitrogen remobilization from vegetative to reproductive parts, possibly explaining the lower dry matter accumulation in the control treatment (Hammad et al., 2011). Furthermore, sufficient nitrogen supply enhances maize plant growth by promoting rapid release and mineralization, leading to increased photosynthetic surface and leaf area index (LAI), ultimately contributing to greater dry matter production (Shanti et al., 1997).

Maize plants showed higher total dry matter with 101 thousand plants ha^{-1} than with 69 and 55 thousand plants ha^{-1}, but it was similar to 85 thousand plants ha^{-1} at silking (75DAS) and physiological maturity (150DAS). Furthermore, 85 thousand plants ha^{-1} had significantly more dry matter than 55 thousand plants ha-1 but was comparable to 69 thousand plants ha^{-1}.

Thus, a difference of 30 thousand plants ha^{-1} was needed to have significant difference between the treatments with respect to dry matter accumulation. In this context, Lakshmi et al. (2014) mentioned that the availability of wider space between rows and closer intra-rows assist in increasing root proliferation which eventually utilizes the resources such as water, nutrients, space and light very effectively that helps to increase functional leaves and in turn enhance the leaf area index leading to higher photosynthetic rate which leads to more dry matter production per plant and consequently per unit per area.

Figure 4

Total Dry Matter of Hybrid Maize as Influenced by Different Level Nitrogen

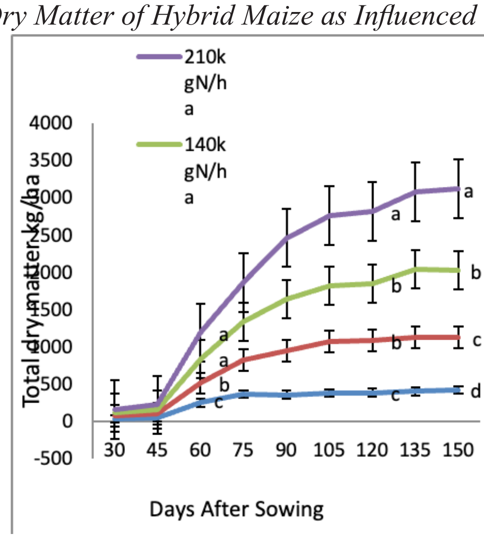


Figure 5

Total Dry Matter of Hybrid Maize as Influenced by Plant Population

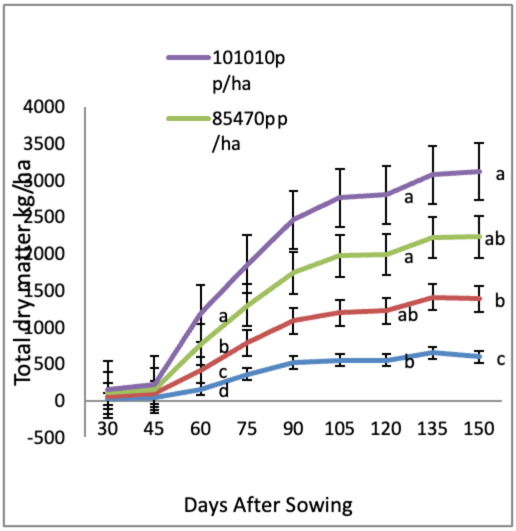


Table 3

Leaf Area Index as Influenced by Different Levels of Nitrogen and Plant Population

	Leaf Area Index (LAI) Days After Sowing (DAS)						
Treatments	30	45	60	75	90	105	120
Nitrogen kg/ha							
0	0.47^{b}	0.49^{b}	1.64^{b}	1.84^{b}	1.94^{b}	1.5^{b}	1.4
70	0.53^{ab}	0.61^{ab}	2.01^{ab}	2.31^{ab}	2.01^{ab}	1.82^{ab}	1.73
140	0.67^{a}	0.68^{a}	2.19^{ab}	2.50^{a}	2.31^{a}	1.90^{a}	1.74
210	0.69^{a}	0.76^{a}	2.49^{a}	2.93^{a}	2.50^{a}	2.00^{a}	1.91
SEM ±	0.05	0.07	0.23	0.18	0.19	0.71	0.60
$LSD_{0.05}$	0.16	0.40	0.68	0.53	0.32	0.18	Ns
Plants population(ha^{-1})							
55,555	0.41	0.47	1.35^{c}	1.64	1.53	1.52	1.48
69,444	0.48	0.59	1.71^{bc}	1.88	1.71	1.64	1.58
85,470	0.72	0.79	2.32^{ab}	2.47	1.98	1.83	1.77
101010	0.75	0.83	2.94^{a}	2.97	2.23	2.14	1.80
SEM ±	0.10	0.11	0.25	0.22	0.18	0.24	0.17
$LSD_{0.05}$	ns	ns	0.88	ns	ns	ns	ns
CV %	32.10	40.80	39	31.3	35.6	42.90	42.90
Grand Mean	0.59	0.64	2.08	2.31	2.02	1.79	1.68

Means followed by the common letter within each column are not significantly different at a 5 % level of significance by DMRT. ns = non-significant

Leaf area index was influenced significantly with increase in nitrogen levels from 0 to 210 $kgNha^{-1}$. Thus, the values of LAI obtained with the application of 140$kgNha^{-1}$ were significantly higher as compared to 210, 70 and 0 $kgNha^{-1}$ which remained at par with 210 and 70$kgNha^{-1}$ except in 45 (after knee high stage) & 60 (before tasseling stage) DAS and 90 (after silking stage) & 105 (before milking stage) DAS, respectively. Contrastingly, plant population levels did not significantly impact leaf area index in this experiment, except at 60DAS. Nevertheless, the findings indicated a slight and insignificant increase in LAI with a higher plant population. Jasemi et al. (2013) observed that plants with more nitrogen had higher leaf area index (LAI) than the control group, which they ascribed to increased leaf production and longer leaf area duration. Higher nitrogen rates most likely enhanced cell growth and hastened leaf area development through quicker cell division, which in turn enhanced photosynthate synthesis and raised LAI (Amanullah et al., 2009). Moreover, Rao & Padmaja (1994) stated that the impact of phytochrome in promoting cell division, enlargement, differentiation, and multiplication under elevated nitrogen levels led to a consistent and statistically significant rise in leaf area index (LAI).

The result of the experiment (table 3) indicates that LAI values were increasing insignificantly with the levels of plant populations at almost all growth stages. In low plant populations, maize cannot offset diminished leaf area through branching or tillering, unlike many tillering grasses. Conversely, high plant density increases competition among plants for light, water, and nutrients, potentially impeding the growth and development of maize crops (Bisht et al., 2012).

Conclusion

The growth and phenology of winter hybrid maize were significantly affected by the proper choices of nitrogen dose and optimum plant population. Plant height, total dry matter accumulation, leaf area index, different phenological stages of hybrid maize (RML95/RML96) was found better in 140 $kgNha^{-1}$ with maintaining 85000 plants ha^{-1} for winter season . The study provide the insight on nitrogen dose and plant population impact on hybrid maize development, emphasizing the need for optimized nitrogen and plant density management to enhance plant growth and overall crop yield. However, for the valid conclusion, the repeating of the trail with multi-locations and multi-year is suggested.

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