Synergistic effects of 2, 4-epibrassinolide and NPK fertilizer on okra (*Abelmoschus esculentus* L.) growth and nutrient use efficiency in South-Eastern Nigeria

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Abstract

Tropical soils under high annual precipitation are often characterized by low pH, which is detrimental to crop growth. Here, we explored the optimum rate of NPK fertilizer to combine with 2,4-epibrassinolide (BR) to maximize yield, and nutrient use efficiencies (NUE) of okra on an acidic soil derived from coastal plain sands. Two BR levels [with (BR_1) and without (BR_0)] were studied at four NPK rates [0 kg/ha (control), 100 kg/ha, 200 kg/ha and 300 kg/ha].Soil pH, organic matter content, TN, and available P varied considerably with NPK rates, with or without BR, with the highest levels under 300 kg/ha. With or without BR, plant photosynthetically active radiation, dry matter and fruit yields increased progressively with increasing fertilizer rate. The NUE (agronomic nutrient use efficiency= 11.26 gg^{-1}; physiological nutrient use efficiency= 8.52 g kg^{-1}) at the 100 kg/ha rate was significantly higher than the other rates. Treatment with BR alleviated the inhibition of okra growth under acidic soil by boosting light interception (199.20 µmol $m^{-2}s^{-1}$) for improved photosynthesis and elevating soil pH for enhanced nutrient uptake. Treatment with BR could induce some tolerance of soil acidity, allowing for reasonable fruit yield up to 100 kg/ha NPK rate.

Keywords: Acid soil, plant growth hormone,okra, nutrient use efficiencies

Introduction

Soils derived from coastal plain sands dominate the littoral states of southeastern Nigeria. They are characterized by high acidity and low inherent fertility that could affect sustainable crop production (Ojeniyi, 2000). The soils have low base saturation and cation exchange capacity (CEC) and are thus easily degraded. Okra (*Abelmoschus esculentus*L.) is an important vegetable crop, widely consumed in the world. Global okra production was estimated to be around 9.96 million tonnes, with India leading with 6.18 million tonnes followed by Nigeria with 1.82 million tonnes (FAOSTAT, 2020). In Nigeria, its significant export potential has contributed to foreign exchange earnings (FAO, 2019). Its cultivation extends throughout the tropics and provides income opportunities for farmers. Okra is a relatively low-cost crop to cultivate with a short growth cycle, allowing for multiple harvests in a single growing season (Ojeniyi and Adejoro, 2013). The crop thrives in well-drained, loamy soil with good fertility attributes. A too sandy soil may drain too quickly and lead to water-deficit for the plant, whereas, a too clayey soil becomes waterlogged and could cause root rot (Sharma *et al.,* 2016).

Soil management is important in low fertility areas with natural acidity and poor availability of essential nutrients. Few studies have been conducted on the use of some plant growth regulators to maximize vegetable crop yield in coastal plain soils (Nayak *et al*., 2024; Yadav and Das, 2024). Adequate steps for increasing nutrient use efficiency (NUE) in plants involve applying the right quantity of inputs at the right time by the right method, root zone placement of (NPK) fertilizers, balanced fertilization, supplementary use of organic inputs and bio-fertilizers, correction of micro nutrient deficiency (especially zinc and iron), maintenance of adequate plant population, proper water management practices, and effective weed control (Iren, 2019; FAOSTAT, 2020). Although okra is more widely produced, distributed and utilized than any other vegetable crop throughout the world, its production in Nigeria is constrained by a number of stress factors including lack of adequate soil nutrient (especially macro nutrient) management or supply. Organic fertilizers are sometimes applied to soil by farmers, but mineral fertilizers, such as NPK has almost been little due mainly to their high costs (Olawuyi *et al*., 2010).

Use of inorganic fertilizers can improve okra yields and soil pH, total nutrient content, and nutrient availability, but its use is limited due to scarcity, high cost, nutrient imbalance and soil acidity (Ibrahim *et al*., 2002). Okra seeds treated with three levels of NPK fertilizer (0, 150 and 450 kg NPK ha^{-1}) was reported to have significantly better growth, yield and yield components with its optimum yield at the 150 kg NPK ha^{-1}in derived savanna of Nigeria (Ologun, 2013). Weil (2012) also reported a better performance of okra in Southern guinea savannah soils of Nigeria when treated with NPK fertilizer. Similarly, Atete (2012) reported that increasing the rate of NPK fertilizer led to an increase in the growth and performance of okra varieties to a great extent in Agbede in Edo State, Nigeria. InKwara State University Teaching and Research Farm in Malete, Nigeria, it was observed that yield components in okra such as fresh fruit yield, fruit weight and number of fruits were increased with the application of NPK fertilizer (Emezu, 2013). A research trial in the Department of Agronomy, University of Ibadan was indicative that the application of 250 kg ha^{-1} level of NPK (20:10:10) proved effective in ensuring better performance in okra (Babatola and Olaniyi, 1999); FFD (2002) also recommended the application of 250 kg ha^{-1} level of NPK fertilizer (20:10:10) for better performance of okra in Abuja, Nigeria. However, Obi *et al.* (2005) reported no significant increase in both fresh fruit yield and weight of okra plants with increasing NPK fertilizer treatments. Although, the application of these nutrients proved to enhance yield of okra, there are some limitations such as: low efficiency (due to loss of nutrients through volatilization and leaching), declined soil organic matter content, nutrient imbalance, soil acidification, as well as soil physical degradation and attendant increased incidence of soil erosion (Lege, 2012; Sekar, 2013). Asides, high cost and occasional scarcity of mineral fertilizers have posed a lot of problem to their use as nutrient sources (Guman, 2011).The use of 2,4-epibrassinolide (BR) as a means of maintaining and increasing soil fertility has been advocated (Otie *et al*., 2022). When BR is efficiently and effectively used, ensured sustainable crop productivity by immobilizing nutrients that are susceptible to leaching (Otie *et al.*, 2021). The hormone is usually applied at lower rates, relative to inorganic fertilizers. Improvements of abiotic environmental conditions (Fariduddin *et al*., 2015; Otie *et al*., 2019a, 2019b; Lu *et al*., 2020), as well as the need to reduce cost of fertilizing crops are reasons for advocating its use (Hussain *et al*., 2020).

Recently, remarkable accomplishments have been made using BR in combination with inorganic fertilizers for crop production under soil acidity stress (Vardhini and Anjum, 2015; Otie *et al*., 2016, 2018). It is a plant growth regulator derived from *Brassica,* a genus of plants in the mustard family (*Brassicaceae*). It is considered to strengthen a plants' immunity against various abiotic stresses by improving uptake and translocation of nutrients, thereby, increasing plant growth and production (Hayat *et al*., 2010; Otie *et al*., 2025). But little or no work has been done on the potentials of BR in okra production in the study location, or elsewhere. This research explored the efficacy of BR in promoting nutrient use efficiencies and fruit yield of okra at varying rates of NPK fertilizer.

Materials and methods

The experiment was conducted in a Screen House at the University of Calabar (04˚ 57′-13˚ N, 08˚ 20′E, 39 m above sea level), Nigeria. The mean annual temperature ranges between 27 and 28 ˚C, while the relative humidity is 70-80 %. The rainy season normally starts from March to late October following the dry season from November to late February. Calabar soils are mainly acid sands, classified as *TypicPaleudult* in the *Ultisol* order using the USDA soil taxonomy.

Collection and preparation of research materials

Okra seed used for the study was Clemson Spineless hybrid popularly known for its smooth, spineless pods and high fruit yield (Dimkpa *et al*., 2019), produced by Premier Seeds Nigeria Ltd., Kaduna State, and was obtained from Cross River State Ministry of Agriculture and Natural Resources, Calabar.The NPK 15:15:15 was sourced from Cross River Agricultural Development Project (CRADP), IBB way, Calabar, Nigeria while the *2,4-Epibrassinolide* are manufactured in China, and distributed world-wide by Consult-Tech Company

LTD, Beijing, P.R. China.

Cured poultry manure (PM) was sourced from Cross River State Ministry of Agriculture, Barracks Road, Calabar, shade-dried, crushed and analyzed for nutrient contents as described in Carter and Gregorich (2007). The PM contained (g/100g) 2.10 N, 0.18 P, 0.86 K, 1.04 Ca, 0.53 Mg and 66.80 organic carbon, with a pH of 7.2.

Soil sample preparation

Bulk surface (0-30cm) soil was collected from Faculty of Agriculture Research farm, University of Calabar, Calabar. Auger soil samples were also collected at 0-15 and 15-30 cm plough layers, and composited. A sub-sample of about 2 kg was weighed into different zip lock bags in triplicate and labeled (a, b and c) for basic soil nutrient analysis (pH, carbon, phosphorus, Total N and exchangeable bases) in the Soil Science Research Laboratory of the University of Calabar, Nigeria. The remaining soil samples were air-dried and sieved with a 4 mm sieve. The bulk surface soil was weighed (39.95 kg) to fill each of 32 plastic buckets (15 L) of 30.0 cm height and 25.0 cm diameter, perforated at the base for drainage of any excess water.

Experimental Design and treatments

The treatments were factorial combinations of two levels of 2,4-epibrassinolide (with- BR_1 and without- BR_0) and four rates (kg/ha) of NPK (F_0= 0, F_1= 100, F_2= 200 and F_3= 300, respectively). The treatments were arranged into a completely randomized design and replicated four times to give a total of 32 experimental units.

Seeding and treatment application

The PM was thoroughly incorporated basally with the soil at the recommended rate of 10 tons/ha for okra (Adesina and Wiro, 2020) five days before seeding. Three seeds of okra were sown per pot at 3 cm deep and later thinned to one vigorous seedling 14 days after seeding (DAS). The 2,4-epibrassinolide (BR) was diluted following the manufacturer's recommended rate of 1 mL to 1000 mL (1 litre) of distilled water, and 150 mL was foliar-applied per plant at 18 DAS, while 350 mL was similarly applied at the onset of 50 % flowering (45 DAS), using a hand-held sprayer. The NPK fertilizer was split-applied following the recommended fertilizer rate of 300 kg/ha for hybrid okra (Iyagba *et al*., 2013). The first split was applied at 14 DAS, while the second split was top-dressed at 24 DAS. Pots were checked regularly, and weeds were eliminated manually.

Data collection

Observations and data collection were done every two weeks.

The data collected for okra were:

1. Plant height and number of leaves at 2, 4, 6, and 8 weeks after sowing (WAS).
2. Photosynthetically active radiation ($\mu molm^{-2}s^{-1}$) determined as a spot measurement, using a handheld meter (MQ-100: Quantum Integral Sensor, Apogee Instruments INC. USA) on the youngest matured leaves periodically (4, 6, and 8 WAS) on sunny days.
3. Number of days to 50 % flowering and fruiting.
4. Dry matter and fruit yields.

Agronomic nutrient use efficiency (ANUE)

The fruit yield increase per unit of applied NPK was calculated to determine how much productivity improvement was gained from the fertilizer (Novoa and Loomis, 1981) thus:

ANUE = Fruit yield in fertilized plots (g) – Yield in control plots (g) /
Quantity of fertilizer applied (g)

Where ANUE = Agronomic Nutrient Use Efficiency

Physiological nutrient use efficiency (PNUE)

The increase in okra fruit yield per unit of increased nutrient uptake is physiological nutrient use efficiency (Otie *et al.,* 2016). This was estimated as:

Yield in fertilized plots (g) – Yield in control plots (g) /
Total N concentration in fertilized plots – Total N concentration in control plots

The N (nutrient) concentrations which were in % were converted to g kg^{-1} by multiplying by a factor of 10.

Plant tissue analysis

Leaf samples were collected at 45 days after seeding and at harvest. The stems were also sampled at harvest. All samples were oven dried at 70 °C to a constant weight (about 48 hours). Leaf samples were milled to pass through a 0.5 mm sieve to determine total N uptake using the micro-kjeldah method.

Soil analysis

The soil pH was determined with a pH meter in a 1:2.5 soil: water suspension using a glass-electrode. Total N was determined by micro-Kjeldahl method (Black, 1965) as modified by Jackson (1989). Available phosphorus was extracted with acidic fluoride using the Bray P1 method (Bray and Kurtz, 1945); phosphorus in the extract was determined by the molybdenum blue method of Murphy and Riley (1962). Exchangeable bases (K, Ca, Mg and Na) were extracted with IN NH_4OAc using 1:10 soil solution ratio. Potassium, sodium, calcium and magnesium in the filtrate were determined with an atomic absorption spectrophotometer (Model 6405 UV/visible spectrophotometer, Jenway, U K). Exchangeable acidity was determined by successive leaching of the soil with neutral un-buffered IN KCl using a 1:10 soil liquid ratio. The amount of acidity (H and Al) in the leachate was estimated by titration with 0.05 NaOH to a permanent pink end point using phenolphthalein indicator (Mclean, 1982).Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black (1934).

Statistical analysis

The experimental data were subjected to analysis of variance using the GenStat software 16.1 (GenStat Sixteenth Edition, Rothamsted Experimental Station, Harpenden, UK) to partition the effects of the 2-factor treatments and their interactions. Means were compared using Duncan's new multiple-range test at the 5 % level of probability.

Results and discussion

Soil properties

The chemical properties of the experimental soil before seeding are presented in Table 1. The soil reaction (pH 5.3) was strongly acidic, but the organic matter (SOM) content (12.88

gkg^{-1}) was within the medium range according to Peter and Onweremadu (2015). Total nitrogen (TN) was low (1.50 gkg^{-1}). Low soil nitrogen is a common phenomenon in the soils of Southeastern Nigeria which are naturally poorly endowed with native nitrogen with inherent low levels of organic matter (Adesemuyi and Adekayode, 2019). The available P (10.12 mgkg^{-1}) was moderately high. while the exchangeable bases (cmolkg^{-1}) were generally low, being 1.95 for Ca, 1.22 for Mg, 0.08 for Na and 0.13 for K. The low levels of exchangeable bases are ascribed to leaching of nutrients down the profile, a characteristic of coastal sands under high precipitation (Udoh *et al.,* 2013). The exchangeable acidity (Al^{3+} and H^{+}) values were also low (0.50 and 0.77cmol kg^{-1}).

Table 1 also shows the soil chemical properties following treatment with NPK and 24-epibrassinolide (BR). The pH, organic matter, TN, available P, and exchangeable Ca, Mg, K and Na were generally higher than their background values. Soils treated with fertilizer had higher residual nutrient values than the control, especially in plots that received full fertilizer recommended rate (F_3 = 300 kgha^{-1}), with or without the BR spray. Okra yield responses to inorganic fertilizers have been reported by Adekiya *et al*. (2019). Similarly, 2,4-epibrassinolide has been shown to boost crop yield and quality parameters in plants (Shahbaz and Ashraf, 2007; Otie *et al.,* 2018).

Growth variables

Plant growth (height and leaf-number) and physiological measurement

Table 2 shows the interaction effects of NPK levels and 2,4-epibrassinolide on okra height, number of leaves and photosynthetically active radiation (PAR) across the sampling periods. As expected, the growth attributes were adversely ($p \leq 0.05$) affected by the untreated control plots, but better crop performance was observed across the treated plots with a peak at the 300 kgNPKha^{-1}rate with BR spray. This significant response of growth components could be attributed to the role of applied NPK to the plants. This is supported by the report of Musa *et al.* (2017) that the use of NPK fertilizer could significantly influence the growth of okra. The improvement of some okra growth and yield quality following the application of some plant growth hormones has been recently reported (Abdullah *et al.,* 2024) in Bangladesh. There was a significant ($p \leq 0.05$) increase in PAR with treatment across the sampling days and the lowest values were observed in the control plots. The best use of light energy (199.20 µmol m^{-2}s^{-1}) was recorded in plants that received 300 kg NPK ha^{-1} plus BR at 8 WAS. Photosynthesis is the most important source of energy for plant growth. It has been suggested that the application of nitrogen and phosphorus fertilizers in combination with some plant growth regulators could accelerate the synthesis of chlorophyll and amino acids that are involved in major plant processes (Gupta *et al.,* 2004; Baker, 2008).

Yield attributes

Number of days to 50 % flowering and fruiting, dry matter and fruit yield

The number of days to 50% floweringand fruiting varied inversely with NPK rates up to 200 kg NPK ha^{-1} (Table 3). Plants treated with BR showed significant earliness in flowering and fruit production, but the highest NPK rate considerably delayed flowering and fruiting as previously reported in Mannan *et al.* *(*2013). According to Li *et al.* (2013), spraying of BR could induce early flowering and fruiting due mainly to its ability to activate plants' defense system (antioxidants) against abiotic stress effects.

A reduced biomass production was observed with a reduction in leave and stem dry weight of the okra plants. According to Iyagba *et al.* (2013), fertilizer application could influence growth, biomass and green pod yield in okra. The dry matter yield of okra was significantly affected by fertilizer application (Table 3). Increasing NPK rates improved the biomass weight relative to the control. Treatment with BR similarly boosted the plants' biomass, but the peak biomass yield (18.72 g pot^{-1}) was attained with 300 kg NPK ha^{-1}plus BR (F_1BR_1). Similarly, the fresh fruit yield per plant was lowest ($p \leq 0.05$) without NPK but treatment with BR boosted fruit yield across the pots, with or without the NPK fertilizer. These results are in consonance with those reported in Omotosho and Shittu (2007) and Kolawole *et al.* (2008) that okra performance increased with increasing rate of NPK fertilizer, and the uptake of N, P and K nutrients was much improved at the highest rate of application. Babatola *et al.* (2010) found that elevated rates of NPK fertilizer improved metabolic activities, leading to higher fresh fruit yields in okra. The best yield was recorded in F_1BR_1plots (322.10 kg NPK ha^{-1}) relative to control plots (F_0BR_0 = 71.20 kg NPK ha^{-1}).

Agronomic nutrient use efficiency (ANUE)

Nutrient use efficiency is a critically important concept in the evaluation of crop production systems.Table4represents the combined effects of NPK levels and 2,4-epibrassinolide (BR) on nutrient use efficiencies of okra. There were negligible effects of NPK rates on the ANUE. However, the BR increased the ANUE across the fertilizer levels substantially. Their interactions showed that a significant ($p \leq 0.05$) reduction occurred in ANUE at the 300 kg NPK ha^{-1}rate (2.73 gg^{-1}) (Table 4). This is in line with the report in HazeriNiri *et al.* (2010) that increased fertilizer rates reduced nutrient use efficiencies in plants. However, the BR significantly ($p \leq 0.05$) increased the efficiencies as reported previously (Khan *et al.,* 2002).

Physiological nutrient use efficiency (PNUE)

Physiological nutrient use efficiency (PNUE) is the yield increase in relation to the increase in crop uptake of the nutrient in above ground parts of the plant (Otie *et al.,* 2016). Similar to ANUE, it needs a plot without application of the nutrient of interest to be implemented and requires measurement of nutrient concentrations in crop biomass (shoot and reproductive structures).In the present study, NPK rate at 100 kgha^{-1}(F_1) gave higher PNUE than at the highest (300 kgha^{-1}) rate (Table 4). Physiological nutrient use efficiency which is the increase in fruit yield of okra per unit increase in nutrient uptake (Otie *et al.,* 2016) was enhanced at lower NPK levels. This suggests that nutrient accumulation (input) was greater than fruit production (output). Belete *et al.* (2018) reported higher PNUE when nutrient supply was decreasing as nutrient levels increased. According to Fageria (2016), increasing nutrient use efficiency is critical for achieving target production while using as little fertilizer as possible. Exogenously applied BR increased the PNUE ($p \leq 0.05$), especially at the lowest fertilizer rate (F_1= 100 kg NPK ha^{-1}). Plants typically experience lower nutrient utilization efficiency under stressed conditions. Previous studies have shown that enhancing nutrient assimilation is of vital importance for the normal operation of physiological and biochemical processes in plants (Reguera*et al.,* 2013; Ren*et al.,* 2021), and their nutrient uptake and assimilation efficiency were strongly associated with changes in photosynthetic activities and transport of photosynthates (Erdal, 2019; Ren *et al.,* 2020).

Conclusion

The combined use of NPK and 2,4-epibrassinolide improved the chemical properties of soils and their availability to okra within a short term. The highest yield was recorded at the 300 kg NPK ha^{-1} where nutrient availability was maximized. Treatment with BR optimized the nutrient uptake and use efficiencies at the 100 kg NPK ha^{-1}rate but the fruit yield peaked under the 300 kg NPK ha^{-1}plus with BR (500 mL) treatment.

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Table 1: Effects of NPK fertilizer (F) rates and BR on soil chemical properties

Treatment	pH (H_2O)	OM (gkg^{-1})	TN (gkg^{-1})	Av. P mg kg^{-1}	Ca	Mg ($cmolkg^{-1}$)	K	Na	Al^{3+}	H^+
Pre-cropping	5.3	12.88	1.50	10.12	1.95	1.22	0.13	0.08	0.50	0.77
F x BR										
F_0BR_0	4.670 d	10.033 e	0.407 e	7.507 h	2.61 f	0.30 e	0.07 f	0.06 e	0.20 a	0.97 a
F_0BR_1	6.080 b	16.827 c	0.907 cd	22.430 d	4.43 cd	0.95 d	0.35 d	0.10 cd	0.17 a	0.66 cd
F_1BR_0	5.320 c	12.803 d	0.773 d	10.277 g	3.46 e	0.41 e	0.12 f	0.08 de	0.21 a	0.92 a
F_1BR_1	6.273 b	17.670 c	1.013 c	37.187 c	4.74 c	1.33 c	0.54 c	0.13 c	0.09 a	0.57 de
F_2BR_0	5.087 c	12.853 d	0.773 d	12.697 f	3.87 de	0.48 e	0.11 f	0.08 de	0.15 a	0.80 b
F_2BR_1	6.373 b	20.473 b	1.623 b	50.203 b	5.88 b	1.82 b	0.70 b	0.18 b	0.10 a	0.48 e
F_3BR_0	5.303 c	13.127 d	0.803 d	14.747 e	3.86 de	0.53 e	0.21 e	0.09 d	0.17 a	0.71 c
F_3BR_1	7.117 a	33.773 a	2.243 a	60.100 a	7.30 a	2.41 a	0.98 a	0.28 a	0.10 a	0.35 f

Mean pairs within a column with different letters are significantly different at the 5% probability level according to Duncan's new multiple- range test. NPK level (F); F_0= 0 kg/ha NPK; F_1= 100 kg/ha NPK; F_2= 200 kg/ha NPK; F_3= 300 kg/ha NPK; BR= 2,4-epibrassinolide; BR_0= without BR application; BR_1= with BR application

Table 2: Interaction effect of NPK rates and 2, 4-epibrassinolide (BR) on growth variables and photosynthetically active radiation (PAR) of okra at different sampling periods

Treatment	Plant height (cm)			No. of leaves			PAR (µmol $m^{-2}s^{-1}$)		
F x BR	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS
F_0BR_0	9.050 e	13.90 e	17.50 h	2.00 f	3.00 f	3.50 e	24.87 g	32.98 h	46.05 h
F_0BR_1	17.025 c	21.98 d	65.20 c	4.00 cd	5.00 cd	5.00 d	57.38 d	71.98 d	86.61 d
F_1BR_0	16.30 c	22.58 d	23.65 g	2.75 ef	3.75 ef	4.50 de	35.67 f	46.14 g	51.95 g
F_1BR_1	19.90 b	27.20 c	52.76 e	4.25 bc	5.25 c	6.50 c	69.38 c	86.61 c	98.36 c
F_2BR_0	13.55 d	23.58 d	41.01 f	3.25 de	4.00 e	4.50 de	45.30 e	52.00 f	59.58 f
F_2BR_1	18.85 bc	29.45 b	75.26 b	5.00 ab	6.25 b	8.50 b	78.78 b	95.11 b	123.88 b
F_3BR_0	12.00 d	22.00 d	56.83 d	3.75 cd	4.25 de	4.50 de	55.85 d	66.33 e	67.69 e
F_3BR_1	23.98 a	39.88 a	85.26 a	5.75 a	8.00 a	10.25 a	91.07 a	127.45 a	199.20 a

Mean pairs within a column with different letters are significantly different at the 5% probability level according to Duncan's new multiple- range test. NPK level (F); F_0= 0 kg/ha NPK; F_1= 100 kg/ha NPK; F_2= 200 kg/ha NPK; F_3= 300 kg/ha NPK; BR= 2,4-epibrassinolide; BR_0= without BR application; BR_1= with BR application; WAS= weeks after sowing

Table 3: Effects of NPK rates and 2,4-epibrassinolide (BR) on number of days to 50 % flowering and fruiting, dry matter yield and fruit yield of okra

Treatment F x BR	Days to 50 % flowering	Days to 50 % fruiting	Dry matter yield (g pot^{-1})	Fruit yield (kgha^{-1})
F_0BR_0	74.25 a	80.00 a	2.56 e	71.20 f
F_0BR_1	61.70 c	61.75 d	8.21 c	170.50 d
F_1BR_0	73.25 a	76.00 b	5.04 d	89.70 f
F_1BR_1	56.50 d	57.25 e	8.21 c	249.10 c
F_2BR_0	72.75 a	71.50 c	5.16 d	123.70 e
F_2BR_1	39.25 e	49.25 f	14.67 b	297.00 b
F_3BR_0	69.75 b	70.50 c	5.02 d	128.30 e
F_3BR_1	32.00 f	42.00 g	18.72 a	322.10 a

Mean pairs within a column with different letters are significantly different at the 5% probability level according to Duncan's new multiple-range test. NPK level (F); F_0= 0 kg/ha NPK; F_1= 100 kg/ha NPK; F_2= 200 kg/ha NPK; F_3= 300 kg/ha NPK; BR= 2,4-epibrassinolide; BR_0= without BR application; BR_1= with BR application

Table 4: Effects of NPK fertilizer rates and BR on nutrient use efficiencies of okra

Treatment NPK levels (F)	Agronomic nutrient use efficiency (ANUE, gg^{-1})	Physiological nutrient use efficiency (PNUE, gkg^{-1})
F_1(100 kg/ha)	6.90 a	4.69 a
F_2 (200 kg/ha)	6.40 a	1.02 b
F_3 (300 kg/ha	6.28 a	0.85 b
BR_0 (0 mL)	3.01 b	0.55 b
BR_1 (500 mL)	10.05 a	3.83 a
F x BR		
F_1BR_0	3.55 b	0.87 cd
F_1BR_1	11.26 a	8.52 a
F_2BR_0	3.75 b	0.43 d
F_2BR_1	9.05 a	1.62 b
F_3BR_0	2.73 b	0.36 d
F_3BR_1	9.83 a	1.34bc

Mean pairs within a column with different letters are significantly different at the 5% probability level according to Duncan's new multiple- range test. NPK level (F); F_1= 100 kg/ha NPK; F_2= 200 kg/ha NPK; F_3= 300 kg/ha NPK; BR= 2,4-epibrassinolide; BR_0= without BR application; BR_1= with BR application