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Effect of Phosphorus Levels on Yield Components and Grain Yield of Two Nerica Varieties in Mwea

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Authors' contributions

This work was carried out in collaboration among all authors. Author EEM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NKK and JPGO reviewed the study design and all drafts of the manuscript. Author EEM managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Phosphorus is one macronutrient that commonly gets fixed and accumulates into soils after it has been in use for long, thus becoming readily unavailable to plants in subsequent years. Such scenario is ontological in Mwea where rice farming is practiced, yet this element is one main critical nutrient that plants cannot do without for they need it for root initiation, root development, photosynthesis, grain- formation, grain-filling, as well as yielding. In that view therefore, an experiment was undertaken in Mwea irrigation scheme with the aim of investigating on the influence of phosphorus levels on yield components and grain yield of Nerica 4 and 11. The experiment was laid out in a Randomized Complete Block Design in split-plot arrangement replicated thrice. Two rice varieties (Nerica 4 and Nerica 11) formed main plots and phosphorus levels (0 kg P/ha, 25 kg P/ha, 50 kg P/ha and 75 kg P/ha) formed split plots. Data was collected on appropriate parameters between week 4 and 19 after sowing at intervals of three weeks. Results demonstrated that phosphorus levels significantly influenced the 1000-grain weight and number of panicles in the tested varieties. Additionally, Grain yield mean variation was observed, where highest grain yield of

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0.988 tons per hectare was produced in Nerica 4 on 50 kg P/ha in season 2, while least grain yield of 0.831 tons per hectare was still produced in the same variety on control in season 1, thus 50 kg P/ha on Nerica 4 is recommended for rice farming in Mwea. The study would be used as a body of guidelines and information for judicial, responsible, and promotion of prescribed application of phosphates in Nerica rice farming at planting for realization of higher yields between the two Nerica varieties (Nerica 4 and 11) in Mwea and with like agro ecological areas.

Keywords: Mwea; rice; phosphorus; levels; Nerica; yield.

1. INTRODUCTION

Rice (*Oryza sativa,* L) is one most consumed food by more than half of world's population [1], at the same time making significant energy and protein source for populations in Africa [2]. It is the most popular food crop in Kenya, and third highly cultivated and utilized cereal crop in Kenya [3], though much of the consumed is imported since national production does not meet the existing demand [2]. Such wanting production-trend is attributable to a wide range of causes that include fixed and unavailable phosphorus [4] to rice grown. Certainly, Mwea is experiencing this challenge, which therefore requires application of phosphate fertilizers [5] at planting to crops for yield-increment [6].

The application of phosphates to rice crops energizes uptake of nitrogen, and improves the uptake of micronutrients by rice plants. So far, not all rice genotypes accommodate a wider range of both biotic and abiotic environments [7], hence there was need to screen which ones do tolerate problematic soils [8] like those in Mwea which have high, immobile and unavailable phosphorus to plants. There was therefore a need to isolate which among rice genotypes do respond well to mineral fertilization [1] in a strategy to provide nutrients to crops. To that effect, the screening undertaken fitted in onto upland Nerica cultivars, which also do happen to be most adaptable to Mwea semi-arid conditions. To this point therefore, since there is no information available on yield response of Nerica 4 and 11 to inorganic phosphorus fertilization in Mwea, then it became rational to undertake this study in that locality where the effects of phosphorus levels on yield components and grain yield of two Nerica varieties (Nerica 4 and 11) was evaluated and yields compared accordingly. Perhaps, 1000-grain weight and number of panicles per hill demonstrated significant influence by the treatments applied. This new information obtained will guide farmers on the phosphate application rate to be applied on Nerica 4 and 11 at sowing for realization of significantly improved yields.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted for two growing seasons in Mwea irrigation scheme's-Kirogo farm site which lies at Latitude 0°37' S 37˚20′E, longitude 0°32′ S and 0°46′ S and at altitude of 1159 meters above sea level [10]. Its climate is tropical monsoon. It has two rainy seasons and two dry seasons, with rain being of uneven distribution. Temperature ranges from 15.6°c to 28.6°c with a mean of 22°c. Soil types are classified as red soils with a slightly acidic pH of 6.18 [11], 0.119% N, 107.0% P (ppm) and 0.085 %K me/140 g, while the exact farm site where the trial was set had its soil properties analyzed in the beginning and at the end of the two seasons.

2.2 Experimental Design, Materials, Treatments, Data Collection and Analysis

The experiments were carried out in Randomized Complete Block Design with two Nerica varieties (Nerica 4 and Nerica 11) forming main plots and phosphorus four levels (0, 25, 50 and 75 kg P/ha) forming split plots. Soil sampling and analysis was done before and after harvesting. All the appropriate routine agronomic practices such as water application, weeding, thinning, pricking, disease control, pest control, other fertilizer applications, et cetera were applied as required. Yield components and grain yield data was collected appropriately between the 4^{th} and 19^{th} week after sowing at intervals of three weeks, measured and findings recorded. Collected and recorded data on yield components and grain yield was cleaned and analyzed using Genstat version 15.1 and means separated using Fischer's Protected LSD test [12].

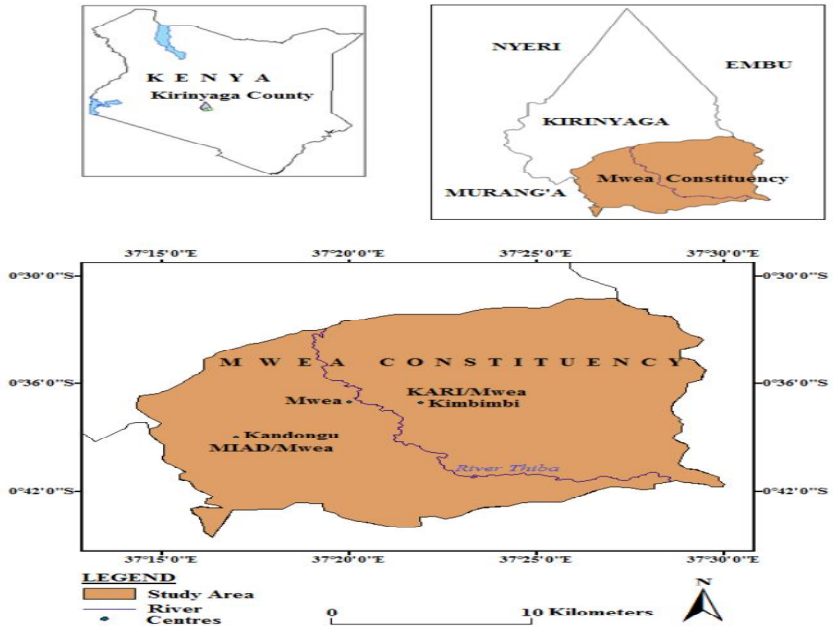

Fig. 1. Map of Kenya showing the study area and site [9]

3. RESULTS AND DISCUSSION

3.1 Plant Height

As per tables 1 & 2, phosphorus level treatments significantly (P≤0.05) influenced plant heights of the two varieties across the seasons throughout crops' growth to maturity, in which maximum height of 72.7 cm in Nerica 4 on 75 kg P/ha in season 2 was recorded (Table 2), while least of 53.33 cm in Nerica 4 on control in season 1 was elicited (Table 1). That necessitated the induction that, with addition of phosphorus into the cultivated soils, plant height increase in the growth stages was made among plants that had been treated with phosphorus than with those that did not receive any phosphorus [13] at all. Such is consistent with Turner et al. [14] who reported that, with increased phosphorus applications, increased plant height was evident due to better root increase and nutrient uptake. That is proven at stem elongation stage where plants for both varieties recorded highest plant height on highest phosphorus treatment than those that had received lower phosphorus applications, and least plant height on control (Tables 1 & 2). Tillering, panicle-initiation, heading, flowering, and grain-formation demonstrated significant plant height increase resulting from the 50 kg P/ha application as compared to other applications, with least plant height recorded at plants that did not receive any phosphorus application (Tables 1 & 2). Plants that did not receive any phosphorus fertilizer for both varieties remained slowly growing from germination until maturity and harvest (Tables 1 & 2); indicating that phosphorus was a limiting growth parameter [15].

3.2 Number of Leaves

The tables (Tables 3 & 4) demonstrate that Phosphorus level treatments significantly (P≤0.05) influenced the number of leaves produced by plants tested in their crop life, where maximum leaf number of 40.78 per hill in Nerica 4 on 50kg P/ha was recorded in season 2, while least leaf number of 23.45 per hill in Nerica 11 on control was recorded in season 1.

Phosphorus is responsible for stimulation of root growth, root development, stem elongation, water absorption and storage [16], nitrogen uptake [17] and cell division, and so with increased phosphorus applications, increased vegetative growth occurs [18]. Such was the case in the experiment where phosphorus effects varied considerably revealing increment in the number of leaves at every stage of rice crop development with increased levels of applications as was reported by Amanullah et al. [19], that with increased phosphorus levels, there occurred increment in growth variables [20] due to increase in leaf photosynthetic rates and

formation of photosynthates. At 50 kg P/ha, maximum leaf number across the seasons was observed at physiological maturity and harvest in season 2 in Nerica 4 plants, while least leaf number was recorded on no-phosphorus applied level in Nerica 11 plants at tillering of season 1. Least leaf number was observed on no-phosphorus applied plants [21] probably due to plant-phosphorus deficiency consequenced by lack of plant-available phosphorus in the soils [22] as evidenced in Table 4.

Table 1. Influence of Phosphorus levels on plant height of two Nerica varieties in Mwea, Season 1

Variety	Weeks after sowing						
	P level (Kg P/ha)	Week 4	Week 7	Week 10	Week 13	Week 16	Week 19
Nerica 11	0	10.09c	24.52c	22.45c	31.76c	48.05c	54.05d
	25	12.01b	25.33b	32.41b	45.5b	52.07bc	56.07c
	50	17.83a	26.63ab	44.02a	58.67a	62.13a	68.13a
	75	14.43ab	28.85a	38.12b	46.38b	54.42b	59.42bc
Nerica 4	0	10.84c	21.67d	21.41c	32.42c	46.33c	53.33d
	25	12.61b	23.18cd	31.1b	47.13ab	55.28b	60.28b
	50	18.21a	24.18c	42.84ab	56.9a	61.63a	65.63ab
	75	15.53ab	25.38b	33.37b	47.43ab	53.67b	58.67bc
	P value	0.045	0.033	0.016	0.042	0.048	0.034
	LSD	0.933	4.119	4.603	2.351	2.791	2.794

Numbers with same letter in the same column are not significantly different using LSD at α=0.05

Table 2. Influence of Phosphorus levels on plant height of two Nerica varieties in Mwea, Season 2

Variety	Weeks after sowing						
	P level(Kg P/ha)	Week 4	Week 7	Week 10	Week 13	Week 16	Week 19
Nerica 11	0	14.75b	24.58b	34.83	49.4c	66.5ab	61.4c
	25	16.92a	25.58ab	40.08a	54.2ab	61c	65.4bc
	50	16.67a	26.08a	42.58a	52.9b	68a	71.3a
	75	17.58a	26.67a	41.67a	56.2a	65ab	68.1ab
Nerica 4	0	13.67c	22.17c	36.33c	54.8ab	64b	67.2b
	25	13c	20.25e	35d	52.8b	67ab	69.8ab
	50	12.42d	19.67e	35.67d	52.9b	69a	72.5a
	75	14.58b	21.83d	38.67ab	55.6a	69a	72.7a
	P value	0.025	0.042	0.029	0.033	0.041	0.029
	LSD	4.086	6.45	6.408	8.99	6.1	8.09

Numbers with same letter in the same column are not significantly different using LSD at α=0.05

Table 3. Response of the number of leaves of two Nerica varieties to phosphorus level treatments in Mwea, Season 1

		Weeks after sowing					
Variety	P level(Kg P/ha)	Week 4	Week 7	Week 10	Week 13	Week 16	Week 19
Nerica 11	0	2.475d	5.68d	17.9d	20.94d	21.32d	23.45d
	25	4.158c	9.92b	22.17b	25.71c	24.15c	26.56bc
	50	8.642a	13.38a	28.08a	30.48a	32.33a	34.16a
	75	5.933b	10.68b	22.88b	26.83bc	25.54b	28.87b
Nerica 4	0	2.375d	5.55d	18.05d	20.84	22.37d	25.68c
	25	4.075c	8.77c	20.25c	26.18bc	24.12c	27.32b
	50	7.975a	13.83a	27.94a	29.84ab	30.19ab	32.87ab
	75	5.825b	9.07b	22.33b	28.2b	24.89c	26.98bc
	P value	0.036	0.019	0.038	0.048	0.022	0.032
	LSD	0.445	1.459	2.814	1.882	1.542	1.542

Numbers with same letter in the same column are not significantly different using LSD at α=0.05

Table 4. Response of number of leaves of two Nerica varieties to Phosphorus level treatments in Mwea, Season 1

Variety	P level(Kg P/ha)	Weeks after sowing					
		Week 4	Week 7	Week 10	Week 13	Week 16	Week 19
Nerica 11	0	9.5ab	15.75e	23.75d	26.98c	34c	35.5c
	25	9.5ab	16.5d	26.42c	28.25b	36.4b	37.3b
	50	8.75c	15.33e	29b	31.22ab	38.2ab	40.12a
	75	9.83ab	18.92b	26.75c	28.92b	36.89b	37.9b
Nerica 4	0	11.42a	20.58a	32.75a	34.56a	40.1a	42a
	25	11.17a	18.83b	24d	26.17c	34.48c	35.87c
	50	9.25b	16.75d	28.83b	30.12ab	39.8ab	40.78a
	75	9.67ab	17.67c	28.67b	31.25ab	38.12ab	39.99ab
	P value	0.032	0.045	0.046	0.015	0.015	0.011
	LSD	1.209	2.334	2.361	5.84	5.82	5.83

Numbers with same letter in the same column are not significantly different using LSD at α=0.05

3.3 Fresh Leaf Weight

In this case, phosphorus level treatments significantly influenced fresh leaf weight between the two varieties in the crop's life across the seasons. This is evidenced in Tables 5 & 6, where highest, higher, lower and least fresh leaf weight was recorded in 75 kg P/ha, 50 kg P/ha, 25 kg P/ha and control at active tillering through other growth stages to physiological maturity. Such direct relationship portrays that with higher level of application, higher osmotic pressure drawing more moisture up on leaves existed and least occurred under control application. That is attributable to the phosphate's energy carrier action of sodium and chloride ions from the soil up the plant's foliage. It was also observable that weight increased significantly from active tillering through stem elongation, panicle initiation, heading, flowering, but decreased gradually at grain formation to physiological maturity in both varieties across the seasons (Tables 5&6); thereby indicating moisture loss as crops neared maturity and subsequent harvest as is normally the case for plants. The two points can be illustrated where maximum fresh leaf weight (10.14 gram per hill) was produced in Nerica 11 on 75 kg P/ha in season 1, while least fresh leaf weight (0.0575 gram per hill) was produced in Nerica 4 on 25 kg P/ha in season 2 (Tables 5&6).

3.4 Dry Leaf Weight

Results in Tables 7&8 herein revealed that the treatments did not have any significant influence (P>0.05) on leaf dry weight of the varieties in both seasons. Nonetheless, variation in means of leaf dry weight was observable right from tillering to physiological maturity where it increased generally at tillering through stem elongation, panicle initiation, heading, and flowering, but dropped decreasingly at grain-formation towards maturity for both varieties in the two seasons. It was also noticeable that maximum dry weight of leaves (7.19 gram per hill) was reached in Nerica 11 on 75 kg P/ha in the 13th week of season 1 after planting probably due to formation of grains that should have undoubtedly ensued from the then accumulated biomass and photosynthates in the leaves. Least leaf dry weight of 0.0289 gram per hill in Nerica 4 under control at active tillering stage of season 2 was also recorded; indicating that at active tillering leaves should have been so young to become sites for photosynthesis since chloroplasts had not formed yet.

3.5 Number of Tillers

Tables 9 &10 herein revealed positive yet lack of significant influence (P>0.05) of the four treatments on tiller number of the tested varieties across the two seasons. Despite the insignificance detected, tiller means gives constructive variation that points at that dismal effect put on the varieties tested, where maximum number of tillers (21 tillers per hill) was produced in at grain-formation stage on 50kg P/ha level of application in Nerica 11 in season 1, while least tiller number (2 tillers per hill) was realized on control treatment in Nerica in both seasons, as well as on 25 kg P/ha in Nerica 4 in the second season. The treatments of 25 kg P/ha at most and 75 kg P/ha influenced moderately on tiller production, although tillers produced as a result of 75 kg P/ha were higher than produced on the 25 kg P/ha treatment, thus affirming the statement of Alam et al. [23] that, phosphorus application on rice plants increased production of tillers (Table 9 & 10). In deed sufficient tillers as

recorded in this experiment should have been an indicator for substantial panicles, filled grains and grain yield recorded at harvest (Tables 17 & 18).

Table 5. Influence of phosphorus level treatments on fresh leaf weight of two Nerica varieties in Mwea, Season 1

Variety	P level(Kg P/ha)	Weeks after sowing					
		Week 4	Week 7	Week 10	Week 13	Week 16	Week 19
Nerica 11	0	0.477ab	0.523b	1.57d	7.23e	0.477a	0.477a
	25	0.479ab	0.531b	1.6c	8.94c	0.477a	0.477a
	50	0.488a	0.515bc	2b	8.68c	0.468b	0.468b
	75	0.493a	0.788a	4.25a	10.14a	0.473a	0.473a
Nerica 4	0	0.447c	0.461c	1.16e	7.98b	0.447a	0.447a
	25	0.461b	0.517bc	1.46d	6.86d	0.429b	0.429b
	50	0.473ab	0.487c	1.68c	7.58d	0.41c	0.41c
	75	0.488a	0.449d	1.82b	9.37ab	0.441a	0.441a
	P value	0.049	0.028	0.045	0.048	0.039	0.039
	LSD	0.1745	0.3151	2.692	3.167	0.1745	0.1745

Numbers with same letter in the same column are not significantly different using LSD at α=0.05

Table 6. Influence of phosphorus level treatments on fresh leaf weight of two Nerica varieties in Mwea, Season 2

Variety	P level(Kg P/ha)	Weeks after sowing					
		Week 4	Week 7	Week 10	Week 13	Week 16	Week 19
Nerica 11	0	0.0617e	0.098d	0.1498b	0.322b	0.319b	0.319b
	25	0.0883c	0.136b	0.1867ab	0.374a	0.369a	0.362a
	50	0.0931b	0.117c	0.1907ab	0.387a	0.372a	0.370a
	75	0.1388a	0.183a	0.2005a	0.31c	0.309bc	0.301bc
Nerica 4	0	0.1092a	0.156ab	0.1577b	0.357ab	0.354ab	0.346a
	25	0.0575f	0.083d	0.188ab	0.273d	0.268c	0.259c
	50	0.0682de	0.095d	0.1386c	0.348ab	0.329b	0.324b
	75	0.0704d	0.095d	0.1497b	0.292d	0.266c	0.263c
	P value	0.0149	0.0186	0.0367	0.0466	0.0295	0.0341
	LSD	0.071	0.097	0.065	0.105	0.1003	0.0876

Numbers with same letter in the same column are not significantly different using LSD at α=0.05

Table 7. Effect of Phosphorus levels on dry leaf weight in Mwea, Season 1

Variety	P level(Kg P/ha)	Weeks after sowing					
		Week 4	Week 7	Week 10	Week 13	Week 16	Week 19
Nerica 11	0	0.1833	0.255	1.261	4.84	0.1833	0.1833
	25	0.1842	0.263	1.265	5.38	0.1857	0.1857
	50	0.1855	0.287	1.279	5.99	0.1865	0.1865
	75	0.1865	0.298	1.283	7.19	0.1955	0.1955
Nerica 4	0	0.1895	0.191	0.927	5.47	0.1918	0.1918
	25	0.1915	0.208	1.225	5.48	0.1918	0.1918
	50	0.1937	0.211	1.246	5.62	0.1943	0.1943
	75	0.1962	0.222	1.913	6.94	0.1955	0.1955
	LSD	NS	NS	NS	NS	NS	NS

Means followed by the same letter in a column are not significantly different using LSD at α=0.05

Table 8. Effect of Phosphorus levels on dry leaf weight in Mwea, Season 2

Season 2	P level(Kg P/ha)	Weeks after sowing					
		Week 4	Week 7	Week 10	Week 13	Week 16	Week 19
Nerica 11	0	0.0337	0.0529	0.0605	0.0848	0.157	0.2538
	25	0.0804	0.0814	0.0818	0.0921	0.183	0.2807
	50	0.0815	0.0827	0.0853	0.0937	0.171	0.2984
	75	0.0899	0.0848	0.0882	0.1025	0.1003	0.2939
Nerica 4	0	0.0289	0.0369	0.0485	0.0834	0.14	0.2302
	25	0.0298	0.0473	0.0598	0.108	0.197	0.2725
	50	0.0337	0.0584	0.0609	0.1048	0.165	0.2648
	75	0.0482	0.0593	0.0628	0.1095	0.131	0.2782
	LSD	NS	NS	NS	NS	NS	NS

Means followed by the same letter in a column are not significantly different using LSD at α=0.05

In addition, there was an observed trend in which 50 kg P/ha happened to have influenced production of highest number of tillers in season 1 particularly, throughout the phenological development of the crop irrespective of their dissimilar genotypes. Also, notable across the seasons was the trend in which on control treatment, lower number of tillers specifically in Nerica 11 plants was realized at active tillering, stem elongation, panicle intiation, heading, flowering until grain formation. Such trend manifested throughout the experiment indicated that phosphorus was limiting in the soil since none was applied, while the extant in the soils prior to sowing was fixed and unavailable to plants.

Table 9. Number of tillers for phosphorus levels on two Nerica varieties in Mwea, Season 2

Variety	P level(Kg P/ha)	Weeks after sowing				
		Week 4	Week 7	Week 10	Week 13	Week 16
Nerica 11	0	2a	3a	6a	10a	16a
	25	3a	5a	8a	11a	16a
	50	6a	8a	11a	14a	21a
	75	6a	7a	9a	12a	17a
Nerica 4	0	3a	4a	6a	10a	16a
	25	4a	5a	8a	11a	17a
	50	6a	8a	10a	14a	20a
	75	6a	8a	8a	11a	17a
	LSD	**NS**	**NS**	**NS**	**NS**	**NS**

Means followed by the same letter in a column are not significantly different using LSD at α=0.05

Table 10. Number of tillers for phosphorus levels on two Nerica varieties in Mwea, Season 2

Variety	P level (Kg P/ha)	Weeks after sowing				
		Week 4	Week 7	Week 10	Week 13	Week 16
Nerica 11	0	2a	4a	6a	11a	11a
	25	3a	5a	7a	12a	15a
	50	3a	5a	7a	10a	15a
	75	3a	5a	7a	12a	12a
Nerica 4	0	3a	5a	6a	13a	14a
	25	2a	5a	7a	11a	12a
	50	3a	5a	7a	12a	14a
	75	4a	7a	9a	13a	13a
	LSD	**NS**	**NS**	**NS**	**NS**	**NS**

Means followed by the same letter in a column are not significantly different using LSD at α=0.05

3.6 Chlorophyll Content

The study exposed significant effect ($P \leq 0.05$) of the treatments on chlorophyll content in two varieties across the seasons throughout crop growth. Tables 11&12 indicates that at active tillering stage, chlorophyll content's produced was highest under 25kg P/ha level on Nerica 11 season 1, while least under control on the same variety in season 2. At stem elongation stage, highest was recorded under 25kg P/ha on Nerica 4 in season 1, and least under the same level on Nerica 4 in season 2. At panicle initiation to heading, highest chlorophyll was produced under 25kg P/ha on Nerica 4 in season1, and least under control on Nerica 11 in the second season. At flowering stage, highest chlorophyll was produced under 75kg P/ha on Nerica 4 in season 2, whereas least produced under control on the same variety in season 2. Lastly in grain formation stage, highest chlorophyll was recorded under 75kg P/ha on Nerica 4 in season 2, while least was recorded under 25kg P/ha on Nerica 4 in the second season. It is therefore considerably inducible that maximum effect of the treatments was revealed at flowering stage where 41.99 SPADS per hill was recorded probably due to the maturity and countless number of chloroplasts present in plants, thereby increasing the surface area on which chlorophyll could be manufactured, while least effect was visible at active tillering where 10.63 SPADS per hill was recorded (Table 12), probably due to less number and immaturity of chloroplasts manufactured, thereby reducing the surface area on which sufficient chlorophyll could be formed in preparation for plant autotrophism expected.

Table 11. Differential influence of four phosphorus levels on chlorophyll content of two Nerica varieties in Mwea, Season 1

Variety	P level(Kg P/ha)	Weeks after sowing				
		Week 4	Week 7	Week 10	Week 13	Week 16
Nerica 11	0	20.49b	30.98b	34.56c	38.62b	36.73bc
	25	22.07a	32.37a	35.72bc	38.96b	37.41a
	50	21.79ab	32.35a	36.07b	37.24c	37.37ab
	75	21.46ab	30.54b	34.24d	37.95bc	36.62bc
Nerica 4	0	19.27c	29.94	36.78b	39.01ab	36.26c
	25	20.17b	31.09ab	38.76a	39.09ab	37.01b
	50	18.48d	29.1c	37.97ab	37.23c	35.36ab
	75	19.23c	30.23b	37.99ab	39.23a	37.43a
	P value	**0.033**	**0.030**	**0.0127**	**0.0132**	**0.0161**
	LSD	**1.522**	**1.511**	**0.549**	**1.123**	**1.051**

Means followed by the same letter in a column are not significantly different using LSD at α=0.05

Table 12. Differential influence of four phosphorus levels on chlorophyll content of two Nerica varieties in Mwea, Season 2

	P level(Kg P/ha)	Weeks after sowing				
		Week 4	Week 7	Week 10	Week 13	Week 16
Nerica 11	0	10.63e	19.44c	28.38c	37.43d	16.37ab
	25	12.42bc	20.68b	30.06b	39.32c	15.77c
	50	15.05a	19.44c	31.23ab	40.73b	16.9a
	75	12.78b	23.68a	31.93ab	41.08ab	16.56ab
Nerica 4	0	12.18c	23.56a	28.94bc	36.51e	16.78ab
	25	11.75d	18.97d	29.26bc	39.68c	16.56ab
	50	14.62ab	22.69b	34.35a	41.1ab	16.83a
	75	14.28ab	20.51bc	34.33a	41.99a	15.83b
	P value	**0.0459**	**0.015**	**0.042**	**0.0272**	**0.009**
	LSD	**4.774**	**6.545**	**6.779**	**5.63**	**1.032**

Means followed by the same letter in a column are not significantly different using LSD at α=0.05

3.7 Panicle Length

Panicle length was significantly affected (P≤0.05) by different levels of phosphorus treatments applied at planting in both seasons. The differential responses in terms of variation in lengths due to four level applications was recognizable right from panicle initiation, heading, flowering, grain formation until physiological maturity & harvest (Tables 13&14). Therefore, at panicle initiation to heading, highest panicle length was elicited under 50 kg P/ha level on Nerica 4 in season 1, while the least was recorded on control on Nerica 11 in season 2; At flowering, highest panicle length was recorded under 50kg P/ha on Nerica 11 in season 1, while least under control on Nerica 11 in season 2; At grain formation, highest panicle length under 50 kg P/ha on Nerica 11 in season 1 was recorded, while least under control on Nerica 11 in season 1 was recorded; and lastly, at physiological maturity, highest panicle length under 50 kg P/ha on Nerica 11 in season 1 was recorded, while least under control on Nerica 11 in season 2 was finally recorded (Tables 13&14). There was an observed trend in which the 50 kg P/ha level happened to have influenced production of highest panicle length, particularly in season 1 throughout the phenological development of crops for varieties under test despite the genotypic differences (Table 13). Also, notable across the seasons was the trend in which, on control treatment, least panicle length specifically in Nerica 11 plants was realized from panicle initiation to physiological maturity. Such trend manifested in the experiment consistently indicated that phosphorus was limiting in the soil since none was applied and on the other hand the extant phosphorus in the soils prior to sowing was fixed and unavailable to plants. On the same note, there was a general trend in both seasons and in all the varieties where the panicle lengths grew longer as plants advanced towards physiological maturity (Tables 13&14); demonstrating the value of panicle length in influencing panicle's role as a contributing factor in rice yields.

Table 13. Panicle length of two Nerica varieties as affected by phosphorous level treatments in Mwea, Season 1

Variety	P level(Kg P/ha)	Weeks after sowing			
		Week 10	Week 13	Week 16	Week 19
Nerica 11	0	7.45b	9.73c	11.13d	12.15e
	25	9.66ab	12.75b	14.57b	14.23d
	50	9.77a	13.58a	15.24a	18.54a
	75	9.69ab	13.23a	14.98b	16.3b
Nerica 4	0	6.86c	9.58c	11.18c	12.11e
	25	9.64ab	12.97b	15.2a	13.72de
	50	9.96a	13.4a	15.22a	18.41a
	75	9.56ab	12.76b	14.44b	15.26c
	P value	0.044	0.03	0.029	0.031
	LSD	1.046	0.877	0.887	1.461

Means followed by the same letter in a column are not significantly different using LSD at α=0.05

Table 14. Panicle length of two Nerica varieties as affected by phosphorous level treatments in Mwea, Season 2

Variety	P level(Kg P/ha)	Weeks after sowing			
		Week 10	Week 13	Week 16	Week 19
Nerica 11	0	12.94c	37.43d	7.92d	20.92a
	25	12.79c	39.32c	10.08b	20.92a
	50	13.58b	40.73b	11.42a	19.55c
	75	12.99c	41.08ab	10.08b	20.02b
Nerica 4	0	13.27b	36.51e	8c	19.22d
	25	12.76c	39.68c	6.83e	20.05b
	50	12.61d	41.1ab	8c	19.5c
	75	15.82a	41.99a	8.5c	19.77c
	P value	0.012	0.0345	0.0384	0.0437
	LSD	2.402	1.078	3.23	2.755

Means followed by the same letter in a column are not significantly different using LSD at α=0.05

3.8 Number of Panicles

The four level treatments significantly influenced (P≤0.05) number of panicles of the tested varieties only at physiological maturity in both seasons, where at physiological maturity, highest number of panicles was elicited under 50kg P/ha on Nerica 11 in season 1, while least under control on the same variety was recorded in season 2 (Tables 15&16). Other stages including panicle initiation, heading, flowering and grain-formation had panicles developed exhibiting positive though insignificant (P>0.05) variation consequenced by four level treatments; at panicle initiation until heading, highest panicle number per was elicited under 25kg P/ha on Nerica 11 in season 2, while least panicle number recorded under 25kg P/ha on Nerica 4 in season 1; at flowering, highest number of panicles was recorded under 50kg P/ha on Nerica 11 in season 2, while least number of panicles recorded under control on Nerica 4 in season 1, and in grain-formation, highest number of panicles was recorded under 50kg P/ha on Nerica 11 in season 1, while least panicle number under control on Nerica 11 in season 2 recorded. Noticeable herein is the trend in which panicle numbers consistently increase as plants advanced to physiological maturity; and indicator of panicle number of a rice plant constituting one crucial component of rice yields. Perhaps, the more sufficient the number of panicles produced, the better capacity the crop has to bring forth sufficient yields.

3.9 Yield Components and Grain Yield

The four phosphorus level treatments significantly influenced (P≤0.05) 1000-grain weight and panicle number in season 1 only, but only presented positive influence albeit insignificant (P>0.05) on other yield components and grain yield in both varieties in the two experimental seasons. The significant influence of phosphorus level treatments on 1000-grain weight in season 1 was evident in Table 17 where under 50kg P/ha treatment, highest 1000-

Table 15. Response of number of panicles of two Nerica varieties to four phosphorus levels in Mwea, Season 1

Variety	P level(Kg P/ha)	Weeks after sowing			
		Week 10	Week 13	Week 16	Week 19
Nerica 11	0	3.63	5.57	12.25	14.71b
	25	4.13	6.2	14.67	16.46a
	50	2.89	6.23	15.58	17.28a
	75	4.1	5.97	13.92	15.87ab
Nerica 4	0	3.34	4.82	12.08	14.34b
	25	2.92	4.88	11	13.76c
	50	3.33	6.04	12.08	14.48b
	75	3.63	5.33	13.25	15.63ab
	P value	0.413	0.872	0.341	0.0341
	LSD	NS	NS	NS	3.456

Numbers with same letter in the same column are not significantly different using LSD at α=0.05

Table 16. Response of number of panicles of two Nerica varieties to four phosphorus levels in Mwea, Season 2

Variety	P level(Kg P/ha)	Weeks after sowing			
		Week 10	Week 13	Week 16	Week 19
Nerica 11	0	3.96	6.33	7.35	8.65d
	25	4.41	7.17	9.39	11.07a
	50	3.34	7.42	8.95	9.85c
	75	4.5	6.92	8.99	10.6b
Nerica 4	0	3.77	5.75	8.96	10.68b
	25	3.34	5.25	8.98	10.95b
	50	3.63	6.67	9.48	11.05a
	75	4.21	6.08	9.55	11.15a
	P value	0.733	0.812	0.779	0.0477
	LSD	NS	NS	NS	4.554

Numbers with same letter in the same column are not significantly different using LSD at α=0.05

Table 17. Effect of phosphorus levels on yield components and grain yield of Nerica varieties in Mwea, season 1

Variety	P-level(Kg P/ha)	Filled grain	Shoot biomass	Root biomass	Productive tillers	Unproductive tillers	Panicle number	1.5 m² plot grain wt(g)	Moisture Content(%)	1000-grain wt(g)	Grain yield (t/ha)
Nerica 11	0	191.4a	22.8a	17.5a	11.24a	0.8a	14.7b	145.9a	12.3a	22.9g	0.973a
	25	147.4a	26.1a	17.9a	12.18a	1.1a	16.5a	130.6a	11.3a	34.5f	0.871a
	50	182.4a	21.2a	17.0a	15.36a	1.3a	17.3a	141.9a	11.8a	70.3b	0.946a
	75	162.5a	22.2a	17.4a	12.97a	1.3a	15.8ab	136.5a	11.9a	60.6c	0.910a
Nerica 4	0	167.9a	21.7a	16.8a	11.38a	0.8a	14.3b	124.6a	12.3a	23.2g	0.831a
	25	152.2a	21.5a	17.5a	12.14a	0.9a	13.8b	122.1a	12.2a	39.7e	0.881a
	50	170.5a	22.5a	17.6a	14.55a	1.0a	14.5b	144.3a	11.7a	76.3a	0.962a
	75	154.5a	22.5a	18.5a	13.43a	1.2a	15.6ab	135.1a	12.1a	54.9d	0.901a
	P value	0.961	0.153	0.32	0.651	0.886	0.041	0.45	0.488	0.004	0.45
	LSD	78.99	6.262	1.532	1.461	0.5317	2.354	23.71	1	4.83	0.1581

Numbers with same letter in the same column are not significantly different using LSD at α=0.05

Table 18. Effect of phosphorus levels on yield components and yield of two Nerica varieties in Mwea, Season 2

Variety	P- level(kg P/ha)	Filled grain	Shoot biomass	Root biomass	Productive tillers	Unproductive tillers	Panicle number	1.5 m² plot grain wt(g)	Moisture Content (%)	1000-grain wt(g)	Grain yield (t/ha)
Nerica 11	0	90.6a	0.185a	0.178a	11a	1a	8.7a	146.6a	13.4a	20.2a	0.977a
	25	85.8a	0.170a	0.187a	11a	2a	11.1a	131.3a	12.0a	19.6a	0.875a
	50	88.8a	0.188a	0.265a	13a	1a	9.9a	142.9a	12.5a	19.8a	0.953a
	75	90.5a	0.180a	0.176a	12a	2a	10.6	134.1a	12.4a	19.6a	0.894a
Nerica 4	0	99.2a	0.180a	0.174a	10a	1a	10.7a	124.8a	13.1a	19.9a	0.832a
	25	97.2a	0.159a	0.156a	10a	1a	10.9a	138.1a	13.0a	20.2a	0.921a
	50	90.3a	0.179a	0.178a	11a	1a	11.1a	148.2a	12.2a	20.1a	0.988a
	75	90.2a	0.175a	0.195a	11a	1a	11.2a	137.3a	12.7a	20.3a	0.916a
	P value	0.814	0.963	0.19	0.837	0.44	0.494	0.352	0.366	0.438	0.352
	LSD	19.78	0.0379	0.07109	2.755	0.5828	2.034	25.7	1.192	0.865	0.1713

Numbers with same letter in the same column are not significantly different using LSD at α=0.05

grain weight (76.30 grams) in Nerica 4 was recorded, while least weight of 1000 grains (22.90 grams) was elicited under control in Nerica 11. Under 50 kg P/ha on Nerica 11 in season 1, highest number (17.28) of panicles per hill was elicited, whereas least (13.76) panicles per hill was produced under 25 kg P/ha on Nerica 4 in season 1. These two yield functions did appear to be the only most vital yield attributes in this study that contributed to the grain yield.

Further, Tables 17 & 18 manifested positive, but lack of significant influence of the treatments on productive tillers, unproductive tillers, filled grains, shoot biomass, root biomass, 1.5 m² plot grain weight, grain moisture content and grain yield in both seasons, and on 1000-grain weight and panicles in the second season. Irrespective of such trend, mean variability as noticed in Tables 17 & 18 indicated that there were higher filled grains (191.4 /hill), shoot biomass (26.1 g/hill), root biomass (18.46 g/hill), productive tillers (15.36 tillers/hill), 1.5 m² plot grain weight (148.2 g), moisture content (13.06% / hill) under control, 25 kg P/ha, 75 kg P/ha, 50 kg P/ha, 50 kg P/ha, and control respectively, while least filled grains (85.8 /hill), shoot biomass (0.1587 g/hill), root biomass (0.1555 g/hill), productive tillers (9.82 tillers/hill), 1.5 m² plot grain weight (124.6 g), and grain moisture content (11.26% /hill); all under 25 kg P/ha respectively. In addition, the grain yield of the crops, did not present any significant effect from phosphorus treatments across the seasons, but variation in mean, where highest grain yield of 0.988 tons per hectare was produced in Nerica 4 on 50 kg P/ha in season 2, while least grain yield of 0.831 tons per hectare was also produced in Nerica 4 on control in the second season.

4. CONCLUSION

Inferentially, Phosphorus level treatments on Nerica varieties significantly influenced plant height, leaf number, leaf fresh weight, chlorophyll content, and panicle length in both seasons, and on number of panicles, and 1000-grain weight at physiological maturity and harvest in the first season. These crucial yield components consistently treated as a continuum, and never as individual parameters, extended positive effects of 50-75 kg P/ha applied at the start, towards crop yields in both varieties and especially on grain yields where maximum (0.988 tons/ha) was obtained in Nerica 4 under 50 kg P/ha. It is therefore recommendable for farmers in Mwea to adopt 50-75 kg P/ha on both varieties for better yields, with a bias towards 50 kg P/ha on Nerica 4.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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