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Original Research Article

Screening and evaluation of upland rice (*Oryza sativa* L.) varieties in inundated soil

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Abstract

Poor germination and subsequent low grain yield of dry seeded upland rice in the existing anaerobic and short niche between lowland rice and dry season crops in the inland valley necessitate the screening of 19 rice varieties. The identification of vigorous growth and short duration upland rice variety in anaerobic condition would optimize this niche. The potted experiment was carried out in the screen house of the Department of Crop Science and Horticulture, Federal University Oye-Ekiti, Ikole campus in 2015 to screen and evaluate the performance of upland rice varieties in inundated soils with a view to selecting the suitable variety or varieties that will fit into the existing niche in the inland valley. The experiment was laid in a complete randomization design and replicated three times. The number of leaves, biomass and grain weight plant^{-1} of the varieties were significantly ($P \leq 0.05\%$) different. The number of tillers observed in WAB 56-104, NERICA 4, NERICA 6, NERICA 3, NERICA 5, NERICA 10, NERICA 9, ARICA 4 NERICA 1, FARO 63, FARO 65 and NERICA 8 varieties were significantly ($P < 0.05$) lower than those of *Igbemo* varieties. The numbers of days to 50% flowering of NERICA 1, NERICA 2, NERICA 10, NERICA 5, NERICA 9, NERICA 3, NERICA 7, NERICA 8, ARICA 4 and WAB 56-104 varieties were the lowest. Although *Igbemo* brown, *Igbemo* white varieties had the highest grain yields per plant, their maturity period exceeded the short period. Thus, NERICA 2 and NERICA 5 varieties which had lower number of days to flowering could be considered as candidate varieties that can be optimized in the niche in question.

Keywords: inland valley; varieties; saturated soil; pre-germinated seeds.

INTRODUCTION

Rice (*Oryza sativa L.*) is a staple food for a large share of the world's populace. Rice has become an increasingly important crop in many countries in the world and extensively in tropical Africa. Nigeria is leading in the West Africa sub-region in terms of production and importation of rice and is the second largest importer of rice in the World after China (Statista, 2011). It was estimated that Nigeria imports rice of about 356 billion naira worth annually (ATA, 2011). Rice growing ecologies in Nigeria include Mangrove Swamp which contributes 1% to rice production in Nigeria, Deep water (5%), Irrigated lowland (16%), Rainfed lowland (inland valleys; 48%) and Rainfed upland (30%; Africa Rice Center WARDA/ FAO/ SAA, 2008b). Wetlands in sub-Saharan Africa are estimated to cover 228 million ha (Bergkamp et al., 2000). Inland valleys in Nigeria were estimated at 3mil ha (World Bank, 2006).

Improving the productivity of rice in the inland valleys is important for closing the gap between production and consumption (Adigbo et al., 2013). In the inland valleys, farmers usually grow lowland rice in the main season and vegetables during the dry season farming periods (Adigbo et al., 2007; Rodenburg, 2013). Between these two growing periods is a short time niche that has been under-utilized (Adigbo et al., 2007). This niche is not only short but the period of moisture content is a transitory period (i.e. transition from anaerobic to aerobic condition) and it cannot accommodate another lowland rice crop. Moreover, the available moisture may only be sufficient to sustain early maturing upland rice. The early part of the niche is usually water saturated and is capable of hindering germination and low yield (Adigbo et al., 2007).

Although rice is adapted to semi-aquatic ecology, it has got an innate ability to tolerate submergence to some extent (Ray et al., 2016). However, rice is extremely sensitive to anaerobic conditions during germination (anaerobic germination) and early growth of the embryo (Yamauchi et al., 1993; Ismail et al., 2009; Angaji et al., 2010). Miro and Ismail (2013) reported that low oxygen content in soil causes a reduction in root growth and function, thus reducing nutrients and water uptake. Furthermore, several phytotoxic substances such as reduced iron (Fe^{+2}), manganese (Mn^{+2}), hydrogen sulphide (H_2S), and intermediates of anaerobic carbon metabolism e.g., organic acids accumulate to toxic concentrations. Besides, these changes, according to literature (Drew and Lynch, 1980; Miro and Ismail, 2013; Kirk et al., 2014), could cause injury to roots and the whole plant, and can lead to plant death in severe cases. Tolerance of anaerobic conditions at these early stages is essential for effective direct-seeded rice in the niche in question. Varieties that can germinate in flooded soils could be beneficial for direct-seeded systems in these areas and even for intensive irrigated systems, where early flooding can suppress weeds (Ismail et al., 2012).

Sowing methods of early maturing upland rice were developed in the niche between lowland rice and dry season cropping (Adigbo et al., 2010). But NERICA 1 variety whose pre-germinated seeds did very well was no longer acceptable to the farmers because it lacks the ability to maintain its viability for considerable periods of time and the poor cooking quality. There is therefore the need to screen nineteen varieties of upland rice with ability to germinate in saturated soil.

The hypothesis of this study is that the selected early maturing upland rice variety (varieties) would fit into the niche between lowland rice and dry season vegetable with a view to enhancing the productivity of the inland valley in derived savannah. The objective of this experiment was to screen and evaluate upland rice varieties in inundated soil with a view to selecting the suitable upland rice varieties to enhance the productivity of the inland valley.

MATERIALS AND METHODS

The experiment was conducted in screen house at the Department of Crop Science and Horticulture, Federal University Oye-Ekiti, Ikole campus, with latitude – North 07°48′308, longitude – East 005°29′573 and 548.4 m above ground level (Garmin 72H, GPS model) from July to December 2015. The soil had pH (1:2, soil/water) of 6.8, 0.74 mg kg^{-1} K measured using flame photometry, 10.60 g kg^{-1}organic matter, 2.10 g kg^{-1} total N (macro-Kjeldahl method) and 31.3 mg kg^{-1} Bray extractable P. The textural class of the soil was loamy soil (492.5 g kg^{-1} s and 332.5 g kg^{-1} silt and 175 g kg^{-1} clay) using USDA textural calculator.

The experiment was laid out in Complete Randomization Design (CRD) with three replications. Fifty seven (57) 5-litre plastic buckets were filled with

Table 1. Rice varieties evaluated

VARIETIES	SOURCE
FARO 64	*NACGRAB
FARO 65	NACGRAB
Igbemo **brown**	NACGRAB
I*gbemo* **white**	NACGRAB
FARO 63(ARICA)	NACGRAB
ARICA 4	Africa Rice Center
NERICA 1	Africa Rice Center
WAB 56-104	Africa Rice Center
NERICA 9	Africa Rice Center
NERICA 10	Africa Rice Center
NERICA 5	Africa Rice Center
NERICA 4	Africa Rice Center
NERICA 2	Africa Rice Center
NERICA 3	Africa Rice Center
NERICA 7	Africa Rice Center
NERICA 6	Africa Rice Center
NERICA 8	Africa Rice Center
FARO 44 (lowland as control)	West Africa Agricultural Productivity Programme (WAAPP)
FUNAABO II	Federal University Of Agriculture Abeokuta, Abeokuta, Nigeria.

*NACGRAB: National Center for Genetic Resources and Biotechnology, Ibadan, Nigeria.

8 kg of homogenous top soil obtained from 0 to 15 cm depth, flooded and left for 30 days to allow for soil chemical reactions before planting.

Rice varieties evaluated in the experiment were collected from Africa Rice Center, National Centre for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Nigeria and Federal University of Agriculture (FUNAAB), Abeokuta, Ogun State, Nigeria (Table 1). The seeds of the 19 varieties were pre-germinated by placing 60 seeds of each rice variety into three Petri-dishes (total of 180 seeds for each variety). The 60 seeds contained in each Petri-dishe were soaked in water for 24 hrs, drained and incubated for another 48 hrs at room temperature so as to ensure uniform seedling emergence and good establishment as recommended by (FAO, 1977; Oikeh et al., 2008; Adigbo et al., 2010).

Planting: Twenty pre-germinated seeds of each variety were dibbled into the inundated potted soil and thinned down to 3 seedlings 3 weeks after sowing. Water was always added to the inundated soil in the pots to the brim every other day in order to maintain anaerobic condition.

Fertilizer application: Fertilizer in the form of NPK 12:12:17 + 2% MgO was applied at the rate 120 kg ha at 7 weeks after planting (WAP).

Data collection

The following data were collected on pot basis

Seedling emergence: The seedlings that emerged above the water level were counted 6 days after planting (DAP).

Plant height (cm): Plant height was measured with the aid of graduated ruler from ground level to the tip of the longest leaf at 4, 6, 8 and 10 WAP.

Numbers of leaves: were counted at 2, 4, 6, 8, and 10 WAP.

Numbers of tillers plant^{-1}: The total numbers of tillers for the three seedlings per pot were determined by counting the culms at 4 WAP. Three was deducted from the total count (this accounted for the 3 main culms of the seedlings) and then divided by 3 at 4 WAP.

Number of days to heading: the number of days to heading was calculated from pre-germination to when two of the potted plants attained anthesis.

Panicle weight (g): Three randomly selected panicles were weighed and the mean recorded.

Panicle length (cm): The length of three randomly selected panicles were measured using a graduated ruler.

Number of grains per panicle^{-1}: The numbers of grains panicle^{-1}of five panicles were counted and the average documented.

Weight of grains per plant was determined by weighing the harvested and threshed seeds obtained per pot and dividing by three.

Weight of biomass (cm): was determined by cutting the above ground biomass of the plant in each pot, oven-dried until constant weight was attained at 70 °C and weighed.

Data analysis

All data collected from the crops were subjected to analysis of variance using Gen Stat 12 edition. The means of variables with significant effects were separated using Duncan Multiple Range Test (DMRT) at 5% level of significance.

RESULTS

There were significant differences among the upland rice varieties in all the parameters measured (Table 2). FARO 64, NERICA 3, NERICA 7 and FARO 63 varieties had the highest percentage germination but they were not significantly higher than those of FARO 65, NERICA 1, NERICA 2, NERICA 6, NERICA 8, ARICA 4 and WAB 56-104 varieties whereas *Igbemo* brown had the lowest. *Igbemo* brown plants were consistently the tallest throughout the period of experimentation whereas NERICA 4 variety had the shortest plants. However, NERICA 4 plants were similar in height with those of NERICA 2, NERICA 3, NERICA 8 and FARO 44 at 10 WAP and NERICA 1 at 13WAP.

The emergence of the rice seedling above the water level showed significant differences among the varieties (Table 3). *Igbemo* white had higher number of seedling emergence than NERICA 6 and FUNAABOR II. The number of leaves of *Igbemo* brown and white were significantly ($P < 0.05$) higher than those of NERICA 6 and FUNAABOR II at 4 WAP. However, FARO 44 progressively had the highest number of leaves at 8, 10 and 12 WAP relative to other varieties, whereas WAB 56-104 consistently produced the lowest number of leaves.

The number of tillers ranged between 2.11 and 8.9 for FARO 44 and WAB 56-104 varieties, respectively (Table 4). However, WAB 56-104, NERICA 4, NERICA 6, NERICA 3, NERICA 5, NERICA 10, NERICA 9, ARICA 4 NERICA 1, FARO 63, FARO 65 and NERICA 8 varieties were significantly ($P < 0.05$) lower than those of *Igbemo* varieties.The numbers of days to 50% flowering of NERICA 1, NERICA 10, NERICA 5, NERICA 9, NERICA 3, NERICA 7, NERICA 8, ARICA 4 and WAB 56-104 varieties were the lowest. However, FARO 44 lowland variety, *Igbemo* white and FUNAABOR II upland rice varieties had the highest number of days.

The panicle weight ranged between 1.38 and 3.08 grams for NERICA 1 and *Igbemo* white varieties, respectively. NERICA 6 and *Igbemo* brown varieties had the longest panicle. However, NERICA 1 and NERICA 10 had minimum panicle but not significantly shorter than those of FARO 64, ARICA 4, WAB 56-104, NERICA 9, NERICA 5, NERICA 4, NERICA 3,

Table 2. Percentage germination (%) and plant height (cm) of upland rice varieties in inundated soil

Treatment	Germination percentage (%)	Plant height (cm)				
		4WAP	6WAP	8 WAP	10WAP	12WAP
FARO 64	94.5a	30.3cd	45.2c-e	78.1b-e	99.cde	104.0c
FARO 65	86.7abc	33.1abc	55.5abc	91.9ab	111.0abc	99.2cd
Igbemo **brown**	50.5f	39.6a	61.1a	94.1a	130.6a	178.4a
Igbemo **white**	82.2b-e	35.7abc	54.9a-d	86.5a-d	125.2ab	134.2b
FARO 63	94.4a	30.7cd	46.7b-e	77.2b-e	98.3cde	81.6def
ARICA 4	90.0abc	34.6abc	50.8a-d	75.8b-e	88.0cde	78.8def
NERICA 1	86.1abc	32.5bcd	47.6b-e	80.1a-e	86.1de	68.6f
WAB 56-104	92.2ab	33.0abc	48.3b-e	80.4a-e	86.0de	79.5def
NERICA 9	82.2b-e	31.8bcd	52.8a-d	85.0a-d	92.4cde	84.7c-f
NERICA 10	79.4cde	33.9abc	51.8a-d	89.9abc	93.6cde	70.9f
NERICA 5	73.9de	33.3abc	50.6bcd	81.8a-e	93.1cde	79.0def
NERICA 4	72.8e	25.8d	38.1e	59.7f	80.3e	67.6f
NERICA 2	84.4a-d	29.2cd	47.5b-e	78.3a-e	97.1cde	78.9def
NERICA 3	93.3a	30.6cd	46.4b-e	70.7def	84.1de	82.3def
NERICA 7	93.9a	38.2ab	56.5ab	88.5abc	92.2cde	86.9c-f
NERICA 6	83.9a-d	30.6cd	46.9b-e	80.8a-e	132.0a	96.3cde
NERICA 8	87.2abc	31.5bcd	46.4b-e	68.9ef	80.2e	76.8ef
FARO 44	72.2e	32.6bcd	46.5b-e	68.9ef	79.4e	96.7cde
FUNAABOR II	79.4cde	29.2cd	44.4de	78.0b-e	105.7bcd	129.0b
S.E	4.673	2.920	4.433	6.652	9.913	8.630

WAP = Week after Planting. Means with the same letter(s) within columns are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 3. Number of seedlings at emergence and leaves of upland rice varieties in inundation of soil

Treatment	Seedling number at emergence 6 DAP	Number of leaves (No)				
		4 WAP	6 WAP	8 WAP	10 WAP	12 WAP
FARO 64	16.7ab	4.9ab	6.3b-d	9.4cde	12.9cde	23.6bcd
FARO 65	16.7ab	4.9ab	6.4a-d	7.6de	10.7cde	17.4b-f
Igbemo **brown**	16.0ab	5.3a	7.5ab	11.9abc	15.7c	25.2b
Igbemo **white**	17.3a	5.3a	7.9a	12.5ab	21.2b	24.17bc
FARO 63	15.3ab	4.9ab	6.0b-d	7.3de	10.9cde	16.5c-f
ARICA 4	13.7ab	4.9ab	6.2b-d	7.6de	9.8de	15.5def
NERICA 1	14.7ab	4.5abc	5.6cd	8.2de	11.2cde	17.2b-f
WAB 56-104	14.3ab	4.9ab	5.6cd	6.7e	8.8e	13.5f
NERICA 9	14.3ab	4.9ab	5.8cd	7.2de	12.2cde	16.8c-f
NERICA 10	13.7ab	4.8ab	5.9b-d	7.de	11.0cde	15.8def
NERICA 5	15.7ab	4.9ab	6.1b-d	9.0de	14.1cd	19.3b-f
NERICA 4	16.3ab	4.8ab	6.7a-d	8.4de	9.8de	14.8ef
NERICA 2	16.0ab	5.0ab	6.3b-d	8.6de	13.9cde	21.8b-f
NERICA 3	15.3ab	4.7abc	6.6a-d	7.4de	12.3cde	15.8def
NERICA 7	16.3ab	5.1ab	6.4a-d	8.9de	13.9cde	18.7b-f
NERICA 6	12.7b	4.4bc	6.0b-d	7.9de	10.1de	17.2b-f
NERICA 8	15.0ab	4.6abc	5.3d	7.4de	10.1de	16.2c-f
FARO 44	16.0ab	5.2ab	7.1abc	14.2a	27.9a	38.9a
FUNAABOR II	8.3c	4.0c	6.2b-d	10.0bcd	13.7cd	23.0b-e
S.E	1.735	0.322	0.651	1.248	2.146	3.464

Means with the same letter within columns are not significantly different at 5% level according to Duncan's Multiple Range Test. DAP – Days After Planting, WAP – Weeks After Planting.

Table 4. Number of days to flowering, yield and yield components of upland rice varieties in anaerobic Soil

Treatment	Number of tiller s/plant	Days to 50% flowering	Panicle wt (g)	Panicle length (cm)	No.of grains panicle^{-1}	Biomass/ plant (g)	Weight of grains/plant (g)
FARO 64	6.6b	86.3c	1.95cde	22.2cde	56.8c-f	18.12bc	3.55c
FARO 65	3.8cd	73.7efg	2.32bcd	26.7bc	65.9b-e	18.63b	3.69c
Igbemo **brown**	6.4b	90.7bc	3.02ab	28.1ab	88.7a	23.79a	10.54a
Igbemo **white**	6.5b	92.7ab	3.08a	25.6bcd	81.8ab	21.54a	7.92ab
FARO 63	3.4cd	77.7def	2.46abc	26.6bc	71.9a-d	15.78cde	3.27c
ARICA 4	3.9cd	69.3gh	1.86cde	23.4cde	62.6b-f	15.69cde	1.42c
NERICA 1	3.6cd	67.7h	1.38e	19.9e	42.9ef	13.46de	3.15c
WAB 56-104	2.1d	67.7h	1.84cde	21.7de	51.9def	13.51e	1.44c
NERICA 9	3.7cd	70.0gh	2.00cde	24.0b-e	53.9def	15.22e	3.44c
NERICA 10	3.6cd	68.0h	1.47e	20.2e	41.1f	13.77e	2.82c
NERICA 5	4.0cd	70.7gh	1.92cde	23.2cde	55.5c-f	14.60de	4.93bc
NERICA 4	3.1cd	78.7de	2.05cde	21.5de	59.9b-f	15.18de	4.18c
NERICA 2	5.0bc	74.0efg	1.88cde	25.5bcd	61.4b-f	18.12bc	5.21bc
NERICA 3	3.9cd	72.7fgh	1.96cde	24.1b-e	63.7b-f	14.56de	4.06c
NERICA 7	5.0bc	68.7gh	1.81cde	22.4cde	48.1def	21.50a	3.03c
NERICA 6	3.4cd	80.7d	2.04cde	30.9a	56.5c-f	17.35bcd	2.33c
NERICA 8	3.3cd	72.0gh	1.63de	21.8de	53.9def	16.09b-d	4.05c
FARO 44	8.9a	96.3a	2.80ab	25.8bcd	79.0abc	18.03bc	8.50ab
FUNAABOR II	5.6bc	95.7ab	1.61de	21.2de	70.9a-d	23.75a	1.56c
S.E	1.04	2.361	0.32	1.92	9.98	1.225	1.634

WAP – Weeks After Planting. Means with the same letter within columns are not significantly different at 5% level according to Duncan's Multiple Range Test.
Igbemo brown was consistently, significantly tallest plant while NERICA 4 was the shortest. The number of leaves WAB 56-104 variety had the lowest number leaves whereas *Igbemo* brown and *Igbemo* white had the highest.

NERICA 7, NERICA 8 and FUNAABOR II varieties. The highest number of grains panicle^{-1} was observed in *Igbemo* brown, FARO 44, FUNAABOR II, FARO 63 and *Igbemo* white varieties whereas NERICA 10 produced the lowest number of grains.

Significant differences were observed in the plant biomass. *Igbemo* brown, NERICA 7 and *Igbemo* white varieties produced the highest plant biomass while NERICA 10, NERICA 9 and WAB 56-104 the lowest. The weight of grains per plant from *Igbemo* brown and FARO 44 varieties had the highest. However, ARICA 4 produced the lowest grain weight per plant.

DISCUSSION

The percentage germination of seeds was significantly ($P < 0.05$) different among the varieties. This could be attributed to their respective genetic make-up and the varying storage conditions where the seeds were stored before the experiment. Furthermore, significant difference observed in the number of seedlings at emergence of the varieties could be attributed to the physiological properties of the individual varieties to elongate their shoots during submergence. This corroborated the report of Manigbas et al. (2009) and Kawano et al. (2009) who reported that seedling emergence ability during submergence is related to their ability to use stored starch reserves through amylase activity and anaerobic respiration in rice seedlings. Recently, Adachi et al. (2015) reported similar results that germinating seeds have high amylase activity and high sucrose and glucose concentration. Thus, this can be attributed partly to the vigorous coleoptile elongation and growth of each variety as controlled by genetic factor. The emergence of seedlings in saturated soil ranging between 12.7 and 17.3 was above average number of seeds planted which agreed with the assumption of Adigbo et al. (2010) that the already germinating seedling could continue the process of germination in saturated soil. Thus, seed pre-germination appears to be a potential panacea to poor germination encountered in anaerobic condition.

The variation in plant height among the nineteen varieties was due to inherent differences of the genotypes thus confirming the earlier reports of GRiSP (2013) and Adigbo et al. (2007) that plant height varies with variety and environmental conditions. Similarly, the significant variation observed in the number of leaves among the varieties tested, could be due to the genetic inherence of the variety and this confirmed the report of GRiSP (2013) that reported that leaf production was influenced by the type of variety and the high level of management during the vegetative stage.

Numbers of tillers produced were also significantly different among the varieties. This difference depends on the physiochemical properties which are influenced by the genotype of the varieties. This report is in line with Fageria et al. (1997) and Rani et al. (2006) who reported that tillering characteristics among other factors are very much influenced by the genetic characteristics of the cultivars grown.

The longer growth duration as measured by the number of days to 50% flowering among the varieties were attributed to genetic variability. Similar results were reported by Ebana et al. (2011) stating that number of days to heading can be influenced by genetic factors generating natural variations. Besides, the length of maturity can be deduced from the number of days to heading, consequently standard check FARO 44 lowland variety, *Igbemo* white, *Igbemo* brown and FUNAABOR II varieties with longer number of days to heading are likely to mature late since the days to heading determines the earliness or lateness of the maturity period of rice crops. This corroborated the opinion of ICAR (2009) who posited that a long-duration variety is characterised by longer vegetative phase than a short-duration one, while the reproductive and ripening phases are mostly constant for most of the varieties (30–35 days).Consequently, higher number of days to 50% heading observed in *Igbemo* brown, *Igbemo* white and FUNAABOR II was enough reason to disqualify them as candidate varieties that could fit into the existing niche with short growing period.

According to Rani et al. (2006) and Kishine et al. (2008) who investigated the quality of basmati rice and NERICA varieties, respectively, reported that panicle length and panicle weight are criteria used to determine the quality of a good rice variety. Consequently, *Igbemo* brown qualified to be classified as good quality rice. However, *Igbemo* white and NERICA 6 had only one of the criteria for determining the quality trait (i.e. panicle weight and panicle length, respectively).These qualities are greatly influenced by the genetic factor and the environmental conditions under which the crop was cultivated. The higher biomass of *Igbemo* brown and *Igbemo* white was attributed to their genetic factor and it is a determinant trait for seedling vigor. This result acquiesced with the report of Manigbas et al. (2008) that seedling vigor determined the biomass of the plant in the development of screening methods for anaerobic germination.

Even though *Igbemo* brown, *Igbemo* white are local upland rice varieties and FARO 44 improved lowland rice variety had the highest grain yields, they may not be able to fit into the niche because of their number of days to maturity which exceeded the short period. By estimation, the maturity period of *Igbemo* brown, *Igbemo* white and FARO 44 varieties were 124, 126 and 129 days, respectively, based on the constant number of days for reproductive and ripening phases of rice (ICAR, 2009). Thus, NERICA 2 and NERICA 5 varieties which had comparable grain weight plant^{-1} with those of *Igbemo* white and FARO 44 varieties but lower number of days to flowering (by estimation matures in 104 and 107 days) could be considered as candidate varieties that can be optimized in the niche in question. Based on this experiment, NERICA 2 and NERICA 5 can be recommended to farmers to be grown in the niche between lowland rice and dry season crops.

CONCLUSION

Based on this experiment, it was concluded that NERICA 2 and NERICA 5 were suitable varieties to be grown in the niche between lowland rice and dry season crops. They could therefore be recommended to farmers interested in triple cropping in the inland valleys.

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