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RESEARCH ARTICLE

YIELD POTENTIALS OF RICE VARIETIES UNDER IRRIGATED LOWLAND IN CÔTE D'IVOIRE GUINEA SAVANNAH ZONE

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Abstract

Côte d'Ivoire every year resorts to rice imports to cover its population's needs, due to significant shortfall in national production. This study aimed to assess the yield potentials of 20 rice varieties in irrigated rice farming to enhance national production. The 20 lines were evaluated in a split-plot design with 3 replications and 2 factors. The mainplotwas variety group with 2 levels (improved and local), while the sub-plot was the variety type (cultivar). NPK fertilizer (15-15-15) was applied as basal dressing at 200 g/15 m^2 before transplanting. Urea (CO(NH2)2, 46% N) was applied as top dressing at rates of 14 g/15 m^2 at tillering and 19 g/15 m^2 at flowering. Analysis of variance showed significant differences at the 5% level for grain yield (GY), straw yield (SY), total dry matter (TDM), harvest index (HI), and agronomic efficiency of fertilizer (AE). Furthermore, these analyses revealed that local rice varieties, Koitè and GT11, yielded around 5 tha^{-1}, approximately two-thirds of the hybrids' yields. However, the Danané variety had one of the lowest yields with 1.5 tha^{-1}. The hybrids AR043H, AR034H, and AR051H were statistically identical and the top three in grain yield.Furthermore, the varieties AR043H, AR034H, and AR051H could be recommended to increase rice in Côte d'Ivoire. These results constitute a significant step in the search for genotypes suited to lowland rice cultivation with high yield potential.

Introduction:-

Rice (Oryza sp.) constitutes the staple food for over half of the world's population (Siri, 2012). It plays a major role in the diet of rural and urban households in Africa and is a strategic and priority product for food security in developing countries (Diagne et al., 2013; FAO, 2017).

In West Africa, the rice sector is primarily composed of small-scale producers and artisanal processors, with high transaction costs (for processing, transportation, and marketing). The area planted with rice has increased from 3 million hectares in the 1980s to over 6 million hectares currently, with nearly 2.4 million hectares in Nigeria (Boutsen & Aertsen, 2013).

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In Côte d'Ivoire, rice holds a significant position in the Ivorian food security policy due to its high domestic demand. However, less than half of the rice demand is met by national production, creating an imbalance between supply and demand (Akakpo et al., 2009; Bagal & Vittori, 2010; ONDR, 2012). Consequently, the country is compelled to import significant quantities of rice from the international market, requiring substantial financial resources (CORAF/WECARD, 2009; FIRCA, 2011; MAHRH, 2010; ONDR, 2012). Thus, to reduce the outflow of foreign currency spent on rice imports, the country has implemented a national strategy to promote rice farming with clear self-sufficiency ambitions (ONDR, 2012). One of the main actions of this rice farming promotion strategy involves utilizing lowlands, irrigated plains, and improved varieties to enhance and stabilize yields (Akakpo et al., 2009; Courtois, 1988; NEPAD–PDDAA & FAO, 2005; Raemaekers, 2001; Toure et al., 2009). Despite all measures taken to support national rice farming, paddy rice yields remain relatively low compared to the yielding potential of introduced improved varieties (Chaudhary et al., 2003; Segda, 2006; Siri, 2012). This study was, therefore, conducted to evaluate the yield potentials of 20 rice varieties in irrigated rice farming.

Methods:-

Description of the experimental site

The field trial was conducted in the M'bé II valley (8º06 N, 6º00 W, 180 m), near the village of Tabako, along the Bouaké-Katiola axis, approximately 24 km from the town of Bouaké. The experimental site was situated in a semi-developed irrigated lowland in the Central region of Côte d'Ivoire, featuring a canal serving as the main drainage system.

The surrounding vegetation was secondary, dominated by Leersiahexandra (Poaceae) and Rhyncosporacorymbosa (Cyperaceae). The climate of the site was subtropical with a bimodal rainfall pattern. This climate is characterizedby average annualtemperatures and rainfall of 28ºC and 1200 mm, respectively.

Experimental site

The trial took place on a secondorder plain (100 – 120 m wide) developed on a granito-gneiss substrate with a Fluvisol characterized by a soil pH (H_2O) of 5.5, organic carbon content of 3.12 gkg^{-1}, and total nitrogen content of 0.31 gkg^{-1}. The assimilable phosphorus content (Olsen method) was high at 150 $mgkg^{-1}$, contrasting with the low potassium content of 0.08 $cmolkg^{-1}$. High levels of calcium (3.05 $cmolkg^{-1}$) and magnesium (2.26 $cmolkg^{-1}$) were also determined, with a cation exchange capacity (CEC) of 2.02 $cmolkg^{-1}$. The C:N ratio and [(K:CEC) × 100] ratio showed values of 10.06 and 3.9%, respectively. Prior to the experiment, the land was under a five-year fallow dominated by Leersiahexandra (Poaceae) and Frimbristulisspp (Poaceae).

Plant Material

Two categories of lowland rice varieties were tested: ten local varieties (LV) and ten improved varieties (IV). The ten local rice varieties (LV), including the popular variety WITA9 (used as a control in this experiment), were collected from various regions across Côte d'Ivoire due to their high adoption rates. The ten improved rice varieties (IV) selected at the AfricaRice research station in Saint-Louis (Senegal) constituted the modern varieties tested. These are lowland hybrids with a yielding potential of 10 to 15 tha^{-1}, with parents being ARSH X Sahel 180. Tables 1 and 2 list the characteristics of these varieties.

Nutrient Sources

The mineral fertilizers used in the experiment were NPK (15-15-15) and Urea (CO(NH2)2, 46% N). NPK (15-15-15) and Urea were applied as basal dressing and top dressing, respectively. Two types of herbicides were also used: glyphosate (to eliminate all types of weeds) and propanil (to target only unwanted weeds). The insecticide DECIS (Lambda cyhalothrin) was employed to control insect pests.

Table 1:- Characteristics of local lowland rice varieties collected across Côte d'Ivoire.

Locales varieties	Code	Type	Cycle (days)	Yield (t ha^{-1})
Palawan	VL1	Lowland	120	2 - 3
Djoukemé	VL2	Lowland	180	….
GT11	VL3	Lowland	180	1 - 2
Danané	VL4	Lowland	145	….
Demamba	VL5	Lowland	150	1 - 2
Kouiklonlé	VL6	Lowland	149	1 - 2
Soungrouba	VL7	Lowland	90	….

Marigbè	VL8	Lowland	75	….
WITA 9 (Control)	VL9	Lowland	105	6 - 10
Koitè	VL10	Lowland	70	3

Table 2:- Characteristics of hybrid varieties supplied by Africa Rice from Saint-Louis Research Center, Senegal.

Hybrid varieties	**Code**	**Type**	**Cycle (days)**	**Yield (t ha^{-1})**
AR624H	VA1	Lowland	90 - 120	10 - 15
AR593H	VA2	Lowland	90 - 120	10 - 15
AR034H	VA3	Lowland	90 - 120	10 - 15
AR051H	VA4	Lowland	90 - 120	10 - 15
AR630H	VA5	Lowland	90 - 120	10 - 15
AR043H	VA6	Lowland	90 - 120	10 - 15
AR601H	VA7	Lowland	90 - 120	10 - 15
AR638H	VA8	Lowland	90 - 120	10 - 15
AR629H	VA9	Lowland	90 - 120	10 - 15
AR597H	VA10	Lowland	90 - 120	10 - 15

Experimental setup and trial management:

After clearing an area of 1815 m^2, the experimental plot was plowed using a motorized cultivator for puddling and drainage operations. It was then subdivided into subplots separated by 3 m, within which micro-plots of 15 m^2 (3 m × 5 m) were distributed with a spacing of 1 m using stakes in a split-plot design (Figure 1). The variety group (improved or local) constituted the main factor, while the type of variety (cultivar) was considered the secondary factor.

NPK fertilizer (15-15-15) was applied as basal dressing at a rate of 200 g/15 m^2 before transplanting. Twenty (20) rice varieties, including ten improved and ten local varieties, were transplanted at a spacing of 20 cm × 20 cm, after 21 days in the nursery, with one plant per hill in the micro-plots (Figure 2). Irrigation was provided through the drainage canal with water intake based on water flow. Urea was applied at rates of 14 g/15 m^2 at tillering and 19 g/15 m^2 at flowering. These doses were calculated based on the normal rate per hectare.

A total herbicide treatment (active ingredient: glyphosate isopropylamine salt) was applied after the first plowing at a dose of 360 g L^{-1} to eradicate all plant growth on the site. Another selective herbicide treatment (active ingredient: propanil (360 g L^{-1}) + trichopyr) was applied two weeks after rice transplantation at a dose of 72 g L^{-1} to control weeds. Two weeks after the herbicide treatment, all plots were irrigated to reach and maintain a maximum water height of 5 cm. The insecticide DECIS (Lambda cyhalothrin) was applied at a dose of 30 g L^{-1} when insect attacks occurred. Two manual weedings were made during this trial.

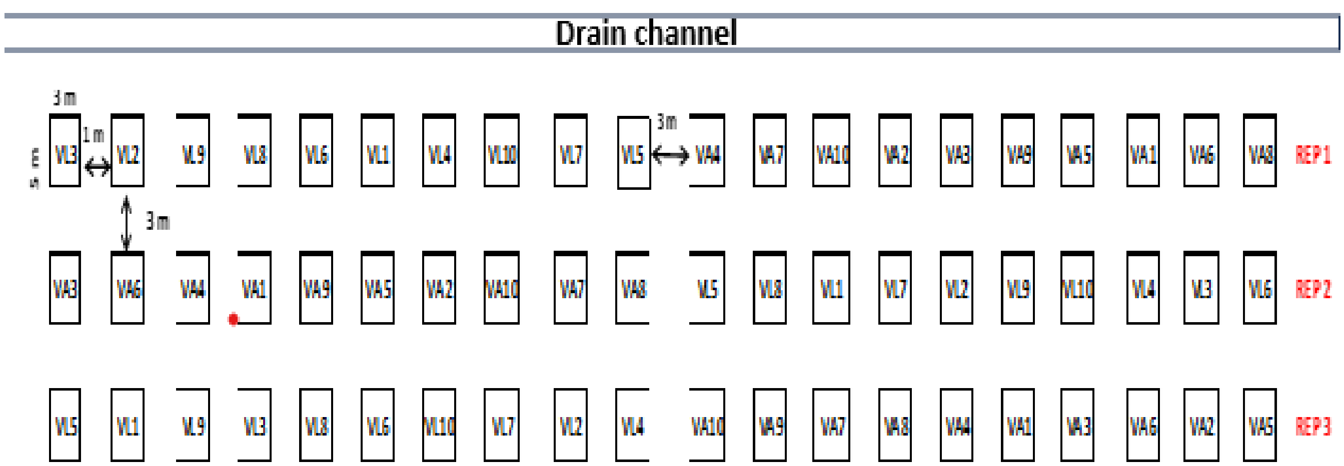

Figure 1:-Split-plot experimental design.

A: Experimental plot B: Hybrid variety AR597H at tillering stage

Figure 2:- General overview of the experimental plot.

Measurement of maturity parameters of lowland rice varieties

At maturity, rice varieties were harvested from an area of 8 m^2 while leaving the two border rows to avoid edge effects. After threshing and drying, the straw was weighed, and the rice grains were winnowed and then weighed. The moisture content of the rice grains was determined after drying in an oven at 70°C for 24 hours. Grain yield was calculated for a standard moisture content set at 14%. Grain yield (GY) and straw yield (SY), total dry matter (TDM), and harvest index (HI) were calculated using the following formulas:

$$\text{Grainyield}(\text{t ha}^{-1}) = \frac{\text{Totaldrygrainweight} \quad (\text{kg})}{8\ (\text{m}^2)} \text{x} \frac{10000}{1000} \text{x} \frac{100-\text{H}}{86} \qquad [1]$$

$$\text{Strawyield}(\text{t ha}^{-1}) = \frac{\text{Totaldrystrawweight} \quad (\text{kg})}{8\ (\text{m}^2)} \text{x} \frac{10000}{1000} \text{x} \frac{100-\text{H}}{86} \qquad [2]$$

Where,

$$\text{H =Humidity}(\%) = \frac{\text{Mass}_{\text{initial}} - \text{Mass}_{\text{final}}}{\text{Mass}_{\text{initial}}} \text{x } 100 \qquad [3]$$

$$\text{Totaldrymatter}(\text{TDM, t ha}^{-1}) = \text{Grainyield}(\text{t ha}^{-1}) + \text{Strawyield}(\text{t ha}^{-1}) \qquad [4]$$

$$\text{HI}(\%) = \frac{\text{Grainyield} \quad (\text{tha}^{-1})}{\text{Totaldrymatter} \quad (\text{tha}^{-1})} \text{x } 100 \qquad [5]$$

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) at the significance level α = 0.05 using SAS software version 9 to test the variety effect(Ledolter, 2010). Classification of the mean values using the Newman and Keuls method allowed for the identification of rice varieties exhibiting the best agronomic performances.

Results and Discussion:-

Grain weight(1000-Grainweight)

Grain weight, determined by grain length, grain width and grain thickness, constitutesa major factorof rice yield(Chen et al., 2021). Means' values of thousandgrainweightof rice varieties were significantly different (P < 0.0001) (Figure 3). Varieties AR638H and Palawan had the highest mean values, while varieties Danané and AR630H were characterized by lower grain weights. Grain weight variation from one variety to another is regulated by several phytohormones like auxin, ethylene, cytokinin, gibberellin and Brassinosteroid(Chen et al., 2021; Li et al., 2021).

Grain yields

Significant differences in the means' values of grain yield were observed across rice varieties (Figure 4). Six hybrid rice varieties, namely AR043H, AR034H, AR051H, AR593H, AR629H, and AR624H recorded higher grain yields compared to the control WITA9. All local varieties had the lowest grain yields as also observed in a study conducted on local and improved varieties in Indonesia (Tenriawaru et al., 2023).

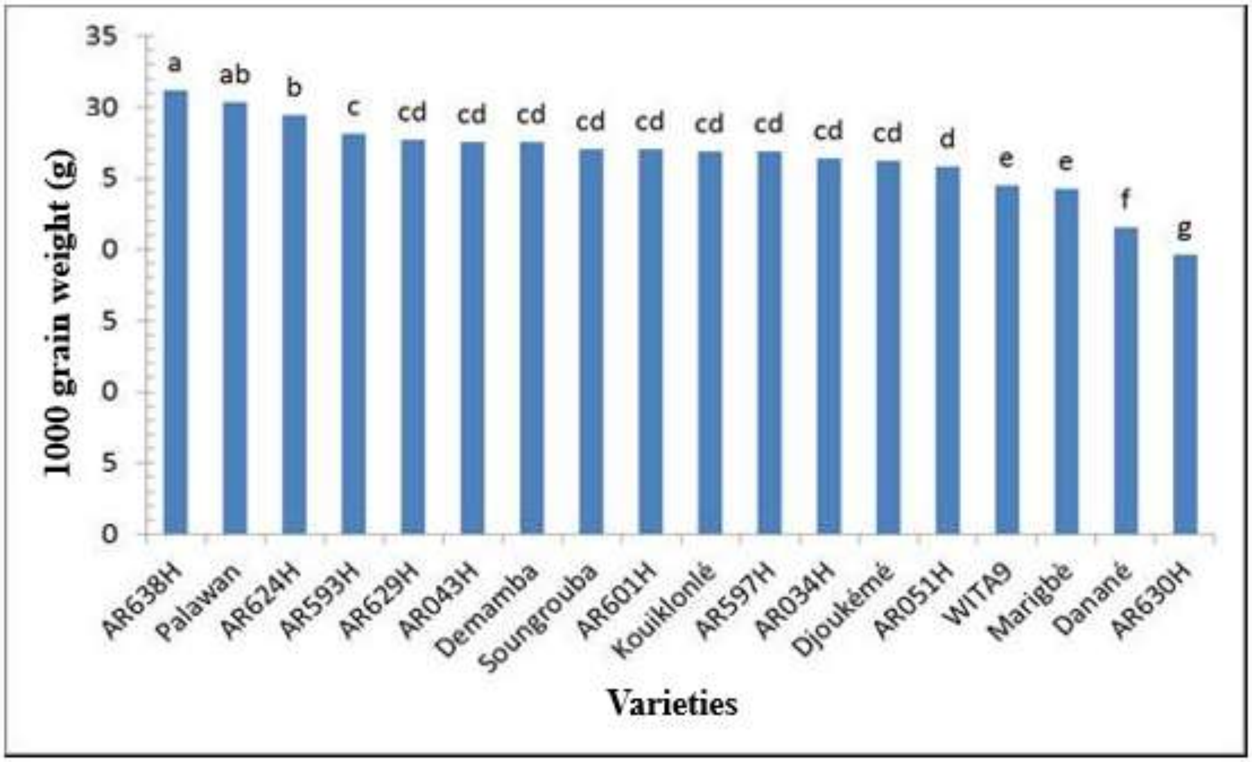

Figure 3:- Average 1000-grain weight of rice varieties(Means followed by the same letters are not statistically different at the $\alpha = 0.05$ level.)

However, the control, a local variety, has produced more grain yield than some improved varieties. Varieties AR043H, AR034H and AR051H had the highest grain yields with approximately 8 tha^{-1} while local varieties Demamba and Kouiklonlé had the lowest yields. Conversely, varieties Koitè and GT11 indicated yields around 5 tha^{-1}. Variety Danané achieved one of the lowest yields of 1.5 tha^{-1}. According to USDA-IPAD(USDA-IPAD, 2024) records regarding rice production, in Côte d'Ivoire, six local varieties, namely Djoukemé, Kouiklonlé, Demamba, Danané, Palawan and Marigbè, produced lesser than the average rice yieldin Côte d'Ivoire.

Straw yield and Total dry matter yields

Figure 5 shows the variation of straw yields of the rice varieties. Significant differences were observed between the means' values of rice varieties straw yields. Six improved varieties, AR638H, AR629H, AR624H, AR051H, AR597H and AR043H, had the highest straw yields. However, there was not significant difference between their straw yields and the one of the control variety WITA9. Moreover, all the local varieties produced lower straw yields than the one of the control.

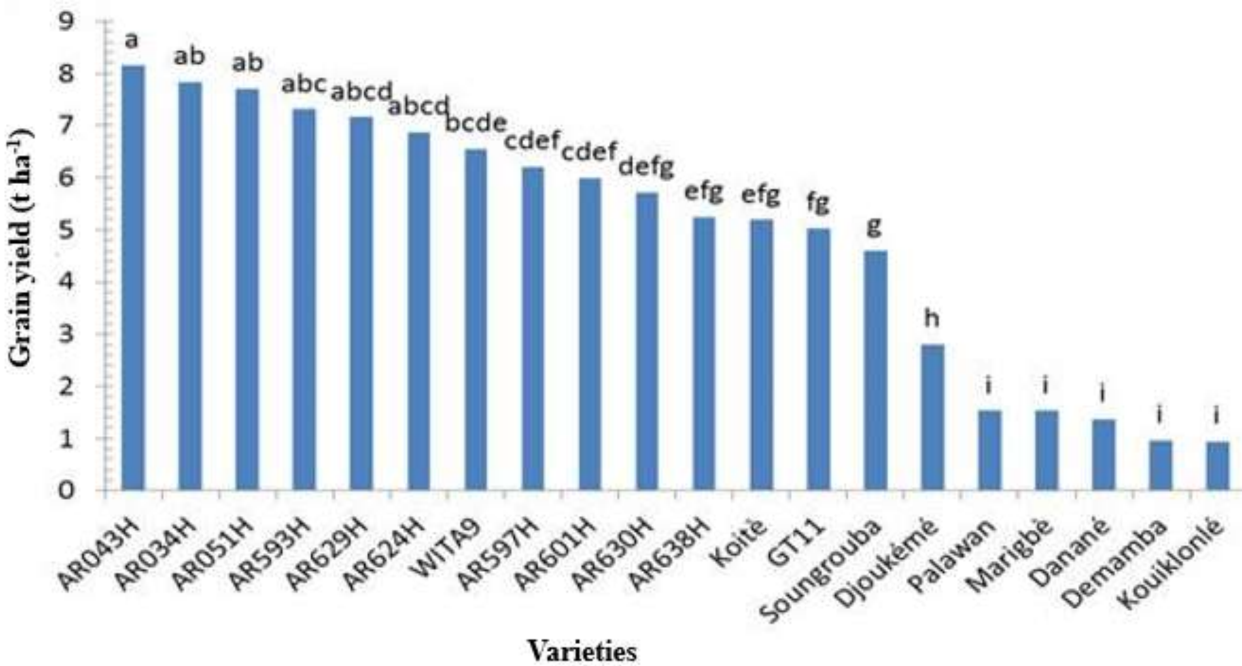

Figure 4:- Mean grain yieldsofrice varieties(Means followed by the same letters are not statistically different at the $\alpha = 0.05$ level).

Seven improved rice varieties, AR629H, AR043H, AR051H, AR638H, AR624H, AR034H and AR597H, recorded a significantly higher total dry matter than that of WITA9 (Figure 6). Local varieties known as Soungrouba and Koitè obtained the highest values among the local varieties, although still lower than the values of the improved varieties.

The varieties AR638H and AR629H presented the best straw yields, around 13 t ha^{-1}, contrasting with the varieties AR043H, AR034H and AR051H with high performance in grain yield. In fact, increased vegetative development can exacerbate the impact of water stress on plant production (Amigues et al., 2006).

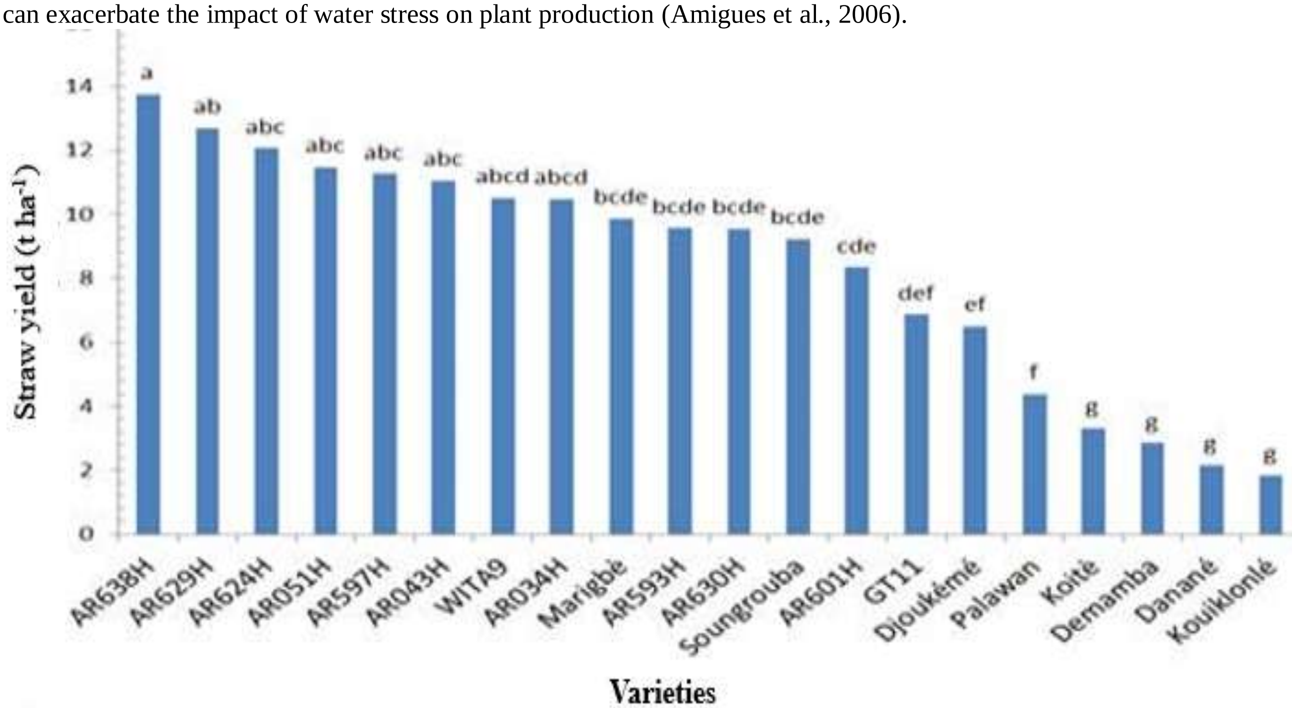

Figure 5:- Mean straw yields of rice varieties(Means followed by the same letters are not statistically different at the $\alpha = 0.05$ level).

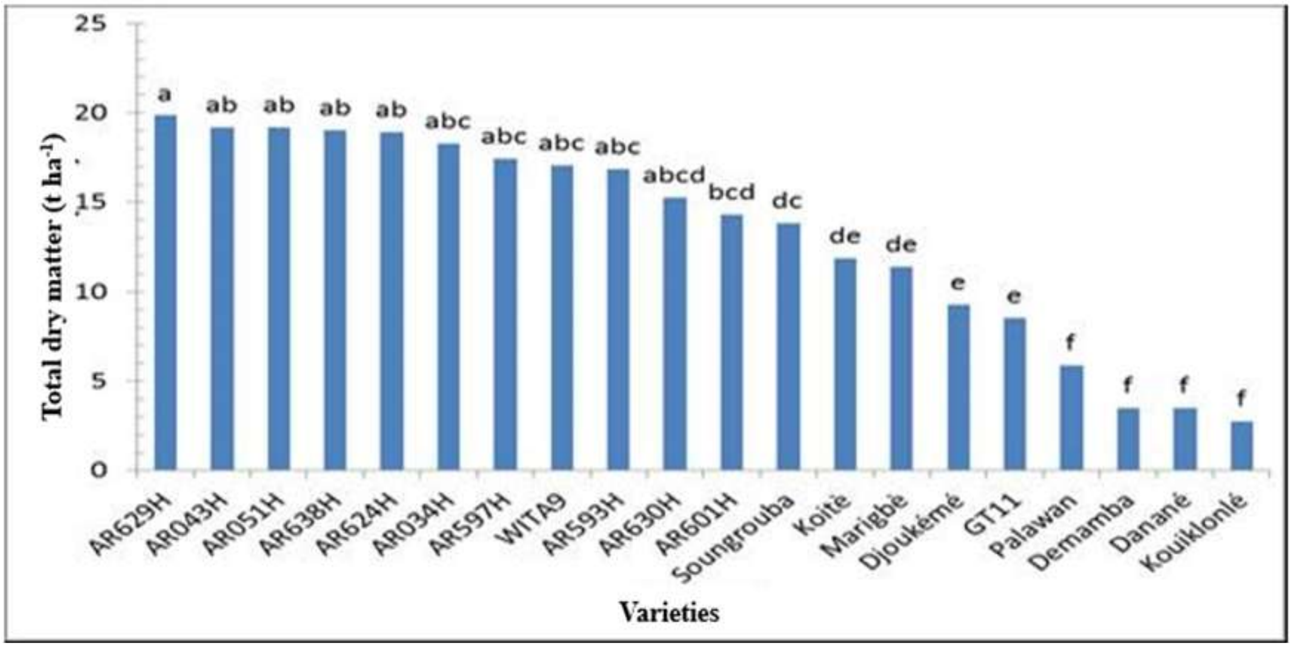

Figure 6:- Mean total dry matter yields across rice varieties (Means followed by the same letters are not statistically different at the α = 0.05 level).

Harvest index (HI)

A significant difference was observed in the mean values of the harvest index (HI) across rice varieties (Figure 7). The local variety Koitè obtained the highest value, exceeding those of the improved varieties AR034H, AR601H, AR593H, and AR043H (> 40%). The local varieties Palawan, Demamba, and Marigbè had the lowest harvest indices.Koitè's harvest index value did notfall in the reported rice harvest indexrange of0.17 – 0.56(Yang & Zhang, 2010). Higher harvest index has been reported as a main characteristicthat supports major improvements in rice yield potential and higher performance of hybrids over inbreds (Lafarge & Bueno, 2009; Sinclair, 2019).The result obtained with Koitè does not follow this observation. This could be due to various parameters including genetics aspect, pedo-geographical locationand water availability (Dwivedi et al., 2023).In fact, rice HI values varied greatly among cultivars, locations, seasons, andecosystems(Fageria, 2007).

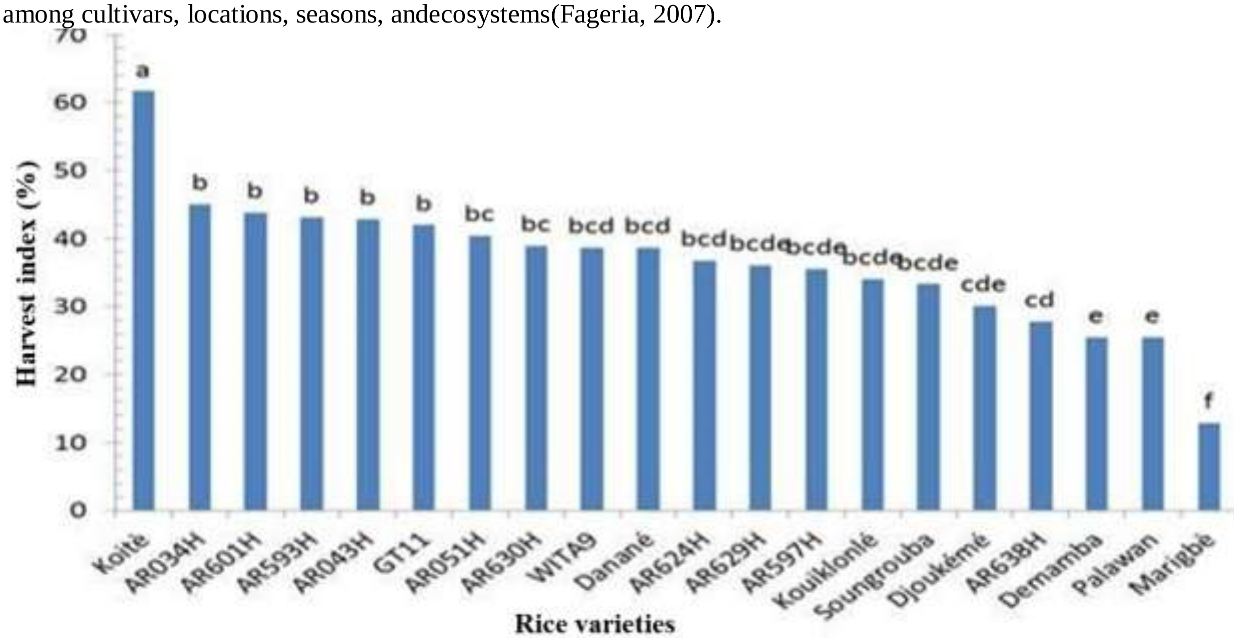

Figure 7:- Mean harvest index values of rice varieties (Means followed by the same letters are not statistically different at the α = 0.05 level).

Conclusion:-

The evaluation of yield potentials of 20 rice varieties in irrigated rice farming showed that the hybrids AR043H, AR034H, and AR051H are statistically identical and are the top three in terms of grain yield. Their harvest indices were above 30%, indicating a good overall harvest. These hybrids exhibited high grain yields (with a maximum of 9 tha^{-1}) and straw yields ranging from 10 to 12 tha^{-1}. However, none of the improved varieties falled into the predicted grain yield range of 10 – 15 t ha^{-1}. Moreover, due to their slender and long grains with a good aroma, the local variety Danané, despite its low yield (1.5 tha^{-1}), could be used as a valuable genetic base for future crosses with some hybrids (AR043H, AR034H, or AR051H). Such crossing should lead to a high-yielding variety comparable to hybrids while keeping the organoleptic characteristics of Danané. These results encourage research activities ongenotypes adapted to lowland rice farming with high yield potential. In this case, molecular biology technology would be required to enhance its nutrient utilization capacity for N, P, and K, which remained very low (< 10%) as observed during this study.

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