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A META-ANALYSIS OF BRRI CONDUCTED TEN YEARS FIELD RESEARCH ON TRANSPLANTED AMAN RICE IN BANGLADESH

N. Parvin[1*], M. A. Salam[2], M. U. Salam[3], M. A. Kader[2], B. Nessa[4], T. Araf[5]

[1]Senior Scientific Officer, Rice Farming Systems Division, Bangladesh Rice Research Institute, Gazipur-1701
[2]Professor, Department of Agronomy, Bangladesh Agricultural University, Mymensingh-2202
[3]Freelance Consultant, 115/3, East Bhurulia, Joydebpur, Gazipur -1700, Bangladesh
[4]Senior Scientific Officer and Head, Sunamganj Regional Station, Bangladesh Rice Research Institute, Shantiganj, Sunamganj- 3000
[5]Scientific Officer, Rice Farming Systems Division, Bangladesh Rice Research Institute, Gazipur-1701
*Corresponding author, E-mail: nargisrfs@gmail.com

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Abstract

In the cropping systems of Bangladesh, T. *Aman* rice has special significance. On the bright side, the crop is grown utilizing monsoonal rain water. On the hind side, it faces natural hazards such as early and terminal drought, and both early and late flooding. Therefore, variety choice and agronomic management are the key considerations for a successful crop harvest. Bangladesh Rice Research Institute (BRRI), the prime rice research institute of the country, routinely conducts large number of trials across the country, accounting for diverse environments, which include performance of varieties and management practices. This study has compiled the body of this knowledge through meta-analysis to generate information using 10-year's meta-data were gathered during the period of 2010 through to 2019. The average yield in meta-data was 7.37 percent higher than national average of T. *Aman* rice yield of Bangladesh. Varieties under High Yield Potential (HYP) category averaged yield of 4.34 t ha^{-1}) and some newer varieties like BRRI dhan72, BRRI dhan79, BRRI dhan87, BRRI dhan76, BRRI dhan78, BRRI dhan80, BRRI dhan90 produced higher yield (above 4.5 t ha^{-1}). Again, many old varieties such as BR 3, BR 4, BR 10, BR 11, BRRI dhan31, BRRI dhan32 produce yield close to 4.5 t ha^{-1}. This study did not find a consistent pattern of response of the three measured management components – transplanting time, seedling age and seedling density. Environmental response on the yield of rice varieties varies between years and locations of the experimentations (environments), indicating environment played a prominent role on yield. Eventually, this study is enough to create the thirst of researchers in the rice research field here some further feasibility of rice yield improvement would emerge from the study of meta-analysis. The results provide a clear message to stakeholders that variety-environment-management synchronized approach is essential for improved yields of T. *Aman* rice in Bangladesh.

Introduction

Agriculture, dominated by crop, is one of the major sectors of developing economy of Bangladesh. Among the crops, cereals occupy about 75 percent of total cropped area, of which about 96 percent belongs to rice (Sarwar and Biswas, 2021). According to Sayeed and Yunus (2018), rice sector provides about 70 percent of agricultural GDP. Rice is grown in Bangladesh throughout the year and centred around three seasons - *Aus*, *Aman* (almost entirely Transplanted *Aman* (T. *Aman*) and *Boro*. While the seasons overlap, the temporal distribution largely follows as mid-March to mid-July for *Aus*, mid-July to mid-November for T. *Aman* and mid-November to mid-March for *Boro*. The seasons accounted for 8.87, 49.31 and 41.82 percent by area and 7.30, 40.93 and percent 51.77 by production for *Aus*, T. *Aman* and *Boro*, respectively.

In the cropping systems of Bangladesh, T. *Aman* rice has special significance. On the bright side, the crop is grown utilizing monsoonal rain water. On the hind side, it faces natural hazards such as early and terminal drought, and both early and late flooding. Therefore, variety choice and agronomic management are the key considerations for a successful crop harvest. Bangladesh Rice Research Institute (BRRI), the prime rice research institute of the country, routinely conducts large number of trials across the country, accounting for diverse environments, which include performance of varieties and management practices. This body of knowledge requires compilation, in a methodical format, to generate information. Garg *et al.* (2008) and Hillebrand *et al.* (2010) have put forward that meta-analysis is a widely used statistical technique that systematically integrates data from multiple related but independent studies and analyses them together to better estimate the real impact of specific interventions or exposures on specific outcomes. This technique allows researchers to draw more robust conclusions than via the analysis of any separate study (Chao *et al.*, 2016). As mentioned by Hernandez *et al.* (2020), individual studies are often insufficient to provide clear results, while larger studies often fail to fully estimate the difference in the risk of rare adverse events. Therefore, a systematic combination of multiple research results, even if they are uncertain or contradictory, helps to more clearly identify true measurements (Andrel *et al.*, 2009; Higgins *et al.*, 2002; Hillebrand *et al.*, 2010). Keeping the views in mind, this study explored the synthesizing a decade-long research-generated rice production technology for T. *Aman* rice.

Materials and Methods

Gathering meta-data

Ten-year's meta-data for the period of 2010 through to 2019 were gathered during the meta-analysis. Those data included the experiments conducted by the Bangladesh Rice Research Institute (BRRI) at the headquarter and regional stations, and documented in published Annual Reports (ARs) and/or unpublished Annual Research Review Reports (ARRRs). Data were sourced from: BRRI 2013a; BRRI 2013b; BRRI 2013c; BRRI 2013d; BRRI 2013e; BRRI 2013f; BRRI 2013g; BRRI 2013h; BRRI 2013i; BRRI 2013j; BRRI 2013k; BRRI 2013l; BRRI 2013m; BRRI 2014a; BRRI 2014b; BRRI 2014c; BRRI 2014d; BRRI 2014e, BRRI 2014f; BRRI 2014g; BRRI 2014h ; BRRI 2014i; BRRI 2014j; BRRI 2014k; BRRI 2014l; BRRI 2014m; BRRI 2014n; BRRI 2014o; BRRI 2014p; BRRI 2014q; BRRI 2014r; BRRI 2014s; BRRI 2014t; BRRI 2014u; BRRI 2014v; BRRI 2014w; BRRI 2014x; BRRI 2014y; BRRI 2014z; BRRI 2014aa; BRRI 2014ab; BRRI 2014ac; BRRI 2014ad; BRRI 2014ae; BRRI 2014af; BRRI 2014ag; BRRI 2014ah; BRRI 2014ai; BRRI 2014aj; BRRI 2014ak; BRRI 2014al; 2014am; BRRI 2014an; BRRI 2014ao; BRRI 2014ap; BRRI 2014aq; BRRI 2014ar; BRRI 2014as; BRRI 2014at; 2014au; BRRI 2015a; BRRI 2015b; BRRI 2015c; BRRI 2015d; BRRI 2015e; BRRI 2015f; BRRI 2015g; BRRI 2015h; BRRI 2015i; BRRI 2015j; BRRI 2015k; BRRI 2015l; BRRI 2015m; BRRI 2015n; BRRI 2015o; BRRI 2015p; BRRI 2015q; BRRI 2015r; BRRI 2015s; BRRI 2015t; BRRI 2015u; BRRI 2016a; BRRI 2016b; BRRI 2016c; BRRI 2016d; BRRI 2016e; BRRI 2016f; BRRI 2016g; BRRI 2016h; BRRI 2016i; BRRI 2016j; BRRI 2016k; BRRI 2016l; BRRI 2016m; BRRI 2016n; BRRI 2016o; BRRI 2016p; BRRI 2016q; BRRI 2016r; BRRI 2016s; BRRI 2016t; BRRI 2016u; BRRI 2016 v; BRRI 2016 w; BRRI 2016 x; BRRI 2016 y; BRRI 2016 z; BRRI 2016 aa; BRRI 2016 ab; BRRI 2016ab; BRRI 2016ac; BRRI 2016ad; BRRI 2016ae; BRRI 2016af; BRRI 2016ag; BRRI 2016ah; BRRI 2016ai; BRRI 2016aj; BRRI 2016ak; BRRI 2016al; 2016am; BRRI 2016an; BRRI 2016ao; BRRI 2016ap; BRRI 2016aq; BRRI 2016ar; BRRI 2016as; BRRI 2016at; 2016au; 2016av; BRRI 2017b; BRRI 2017c; BRRI 2017d; BRRI 2017e; BRRI 2017f; BRRI 2017g; BRRI 2017h; BRRI 2017i; BRRI 2017j; BRRI 2017k; BRRI 2017l; BRRI 2017m; BRRI 2017n; BRRI 2017o; BRRI 2017p; BRRI 2018a; BRRI 2018b; BRRI 2018c; BRRI 2018d; BRRI 2018e; BRRI 2018f; BRRI 2018g; BRRI 2018h; BRRI 2018i; BRRI 2018j; BRRI 2018k;

BRRI 2018l; BRRI 2018m; BRRI 2018n; BRRI 2018o; BRRI 2018p; BRRI 2018q; BRRI 2018r; BRRI 2018s; BRRI 2019a; BRRI 2019b; BRRI 2019c; BRRI 2019d; BRRI 2019e; BRRI 2019f; BRRI 2019g; BRRI 2019h; BRRI 2019i; BRRI 2019j; BRRI 2019k; BRRI 2019l; BRRI 2019m; BRRI 2019n; BRRI 2019o.

The ARs and ARRRs were available electronically. BRRI sourced-data were used because of its national recognition as the prime and dedicated rice research institute, its extensive research coverage across the nation's diverse agroecosystems, and relatively easy availability research data. Data were searched in the sources in the following orderly criteria:

I. The experiments conducted only in T. *Aman* season in conformity of the season for which the present study was undertaken;
II. Treatments of the experiments included named inbreed 'variety' or 'varieties;
III. Under criterion, treatments included one or more of the three sub-treatments: 'transplanting time', 'seedling age' and 'hill density'.

The above search criteria provided altogether 7,203 data-points, termed as 'pooled-data', which were stored in MS-Excel. From those pooled-data, the dataset for 'Variety – Transplanting time – Seedling age – Hill density' were searched. The search resulted in 4491 meta-data points. Those meta-data were used for meta-analysis. The year-wise pooled-data and meta-data are presented in Table 1.

Table 1: Year-wise number of pooled-data and meta-data gathered for meta-analysis

Year	Pooled-data (number)	Meta-data (number)
2010	515	245
2011	575	317
2012	824	609
2013	443	413
2014	618	170
2015	1034	746
2016	938	515
2017	763	516
2018	847	563
2019	646	397
Total	7203	4491

Meta-data categorization

There varieties in screened data-points of 4491 were categorised into four groups such as Aromatic (331 data-points), High Yield Potential or HYP (3870 data-point), Market Demand (47 data-points) and Photosensitive (243 data-points). The study undertook detailed with HYP category considering the sample number of data-points. Among the varieties existed in 3870 data-points of HYP category, two top varieties (BBRI dhan49, data-points 526 and Swarna type, data-points 163) were selected for detailed study.

Meta-data tabulation, processing and quality control

All data were tabulated with unique identifier and curated. Spacing converted to hill per m^2 (hill density) and transplanting date converted to Julian days. During the curation process, where data were not clearly recorded and/or had confusion on understanding, the respected sources were re-visited. After data extraction, an additional round of data editing and quality control of all studies was conducted.

In order to analyse structurally, the meta-data were categorised for (i) variety diversification, (ii) transplanting time and (iii) seedling age and (iv) hill density.

i. Variety diversification: Rice varieties were grouped into four categories in relation to product speciality. They were Aromatic Scented rice, High yield potential (Fertilizer using efficiency is higher and has potentiality to give higher yield, HYP), Market demand (High value rice varieties) that have demand in market for their taste at consumer level and photosensitivity (varieties which have photosensitivity to day length).

ii. Transplanting time: The whole range of the rice transplanting time applied in the meta-data was categorised at 15-day interval into five groups - Very early (Upto14 July, Julian day 195), Early (15 - 29 July, Julian day 196 - 210), Mid (30 July - 13 August, Julian day 211-225), Late (14 - 28 August, Julian day 226 - 240) and very late (After 28 August, Julian day above 240).

iii. Seedling age: The whole range of the seedling age applied in the meta-data was categorised at 10-day interval into four groups, Younger (≤ 30), Middle (31-40), Older (41-50), and very older > 50.

iv. Hill density (hill number per square meter): The whole range of the rice hill density explored in meta-data was categorised into three groups, Standard (<= 30), High (<= 40), and very high (> 40).

Statistical analysis and presentation

Distribution of rice yields in meta-data was analyzed using 'Analysis Tool Pack of MS-Excel' and presented as 'Box-Whisker' graph and 'Histogram'. Variety and management specific yields were compiled using 'Pivot Table' function of MS-Excel. Yields were compared statistically using 95% confident interval. Presentation of the results of meta-analysis followed the following sequence:

(i) Distribution of rice grain yield across all meta-data, to summarize overall yield scenarios, using 'Box-Whisker' graph.

(ii) Frequency distribution of the rice yields on a 1.0 t ha^{-1} interval across all meta-data, to summarize overall data scenarios, using 'Histogram'.

(iii) Relative percentage rice varieties accounted for in meta-data using 'Bar diagram'.

(iv) Relative percentage of rice variety group accounted for in meta-data according to purpose of growing 'Bar diagram'.

(v) Relative percentage of the variety and yield distribution of rice grain yield by variety group (defined as 'purpose of growing') accounted for in meta-data using 'Bar diagram' and 'Box-Whisker' graph, respectively.

(vi) Relative percentage of rice varieties under 'HYP' group accounted for in meta-data using 'Bar diagram'.

(vii) Grain yield distribution of rice varieties under 'HYP' group accounted for in meta-data using 'Bar diagram' and 95% confidence interval.

(viii) Distribution of rice grain yield of BRRI dhan49 and Swarna type accounted for in meta-data 'Box-Whisker' graph.

(ix) Response of transplanting time across the varieties under 'HYP' group accounted for in meta-data using 'Bar diagram' and 95% confidence interval.

(x) Response of transplanting time on of BRRI dhan49 and Swarna type rice varieties accounted for in meta-data using 'Bar diagram' and 95% confidence interval.

(xi) Response of seedling age across the varieties under 'HYP' group accounted for in meta-data using 'Bar diagram' and 95% confidence interval.

(xii) Response of seedling age on of BRRI dhan49 and Swarna type rice varieties accounted for in meta-data using 'Bar diagram' and 95% confidence interval.

(xiii) Response of hill density across the varieties under 'HYP' category accounted for in meta-data using 'Bar diagram' and 95% confidence interval.

(xiv) Response of hill density on of BRRI dhan49 and Swarna type rice varieties accounted for in meta-data using 'Bar diagram' and 95% confidence interval.

(xv) Spread of rice yield, year-by-year, across the varieties under 'HYP' group accounted for in meta-data using 'Bar diagram' and 95% confidence interval.
(xvi) Spread of rice yield, location-by-location, across the varieties under 'HYP' group accounted for in meta-data using 'Bar diagram' and 95% confidence interval.
(xvii) Spread of rice yield of the variety 'BRRI dhan49' across the environments designated in the meta-data sources and presented in a matrix of location (district) and season (year). This is a compilation of 526 data-points. Number in a matrix represented the average of the yields for the matrix. The matrices were also represented by colored circles across the yield gradient: => 5 t ha^{-1}(green), 4 to <5 t ha^{-1} (yellow), 3 to <4 t ha^{-1} (black) and <3 t ha^{-1} (red).
(xviii) Spread of rice yield of the variety 'Swarna type' across the environments designated in the meta-data sources and presented in a matrix of location (district) and season (year). This is a compilation of 163 data-points. Number in a matrix represented the average of the yields for the matrix. The matrices were also represented by coloured circles across the yield gradient: => 5 t ha^{-1} (green), 4 to <5 t ha^{-1} (yellow), 3 to <4 t ha^{-1} (black) and <3 t ha^{-1} (red).

Results and Discussion

Distribution of rice grain yield

The yields ranged from 0.03 to 7.76 t ha^{-1}, where the middle 50% of the yield data concentrated within 3.50 to 5.04 t ha^{-1}; the average yield was 4.22 t ha^{-1} and the median of yields was 4.30 t ha^{-1} (Fig. 1). The average yield was 7.37 percent higher than national average of T. *Aman* rice yield of Bangladesh, 3.93 t ha^{-1} (equivalent clean rice yield of 2.63 t ha^{-1}) as of 2019-20 data, BRRI, 2021b).

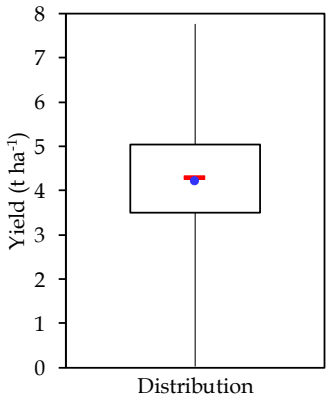

Fig. 1. Distribution of rice grain yield in T. *Aman* season recorded in 10 years research (2010 - 2019) accumulated in meta-data. Box represents middle 50% of the yields, vertical line is the range, and within the box, horizontal line is the median and solid circle is the average

Frequency distribution of the rice yields in meta-data is presented in Fig. 2. Results indicate that, the yields were slightly skewed towards lower ends. The maximum frequency (35.3%) of the yields concentrated on 4.0 - 5.0 t ha^{-1}, followed by 24.3 and 21.8% at 3.0 - 4.0 t ha^{-1} and 5.0 - 6.0 t ha^{-1}, respectively. A small segment of experiments (0.9%) recorded comparatively low yield (0.0 - 1.0 t ha^{-1}); on the other hand, 0.2% experiments achieved comparatively high yield (7.0 – 8.0 t ha^{-1}).

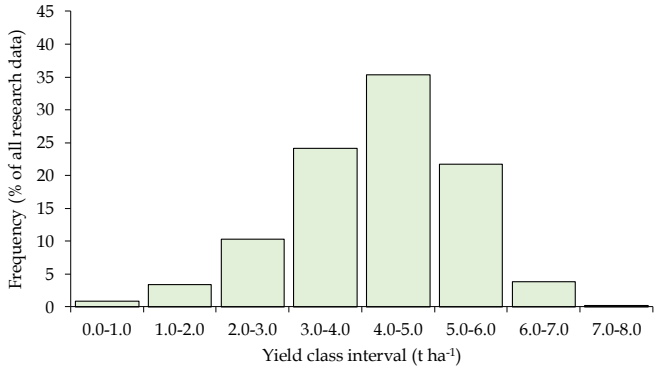

Fig. 2. Frequency distribution of rice grain yield in T. *Aman* season recorded for 10 years research (2010 - 2019) accumulated in meta-data

Rice varieties accounted for in meta-data

The meta-data recorded as many as 69 rice varieties (Fig. 3).

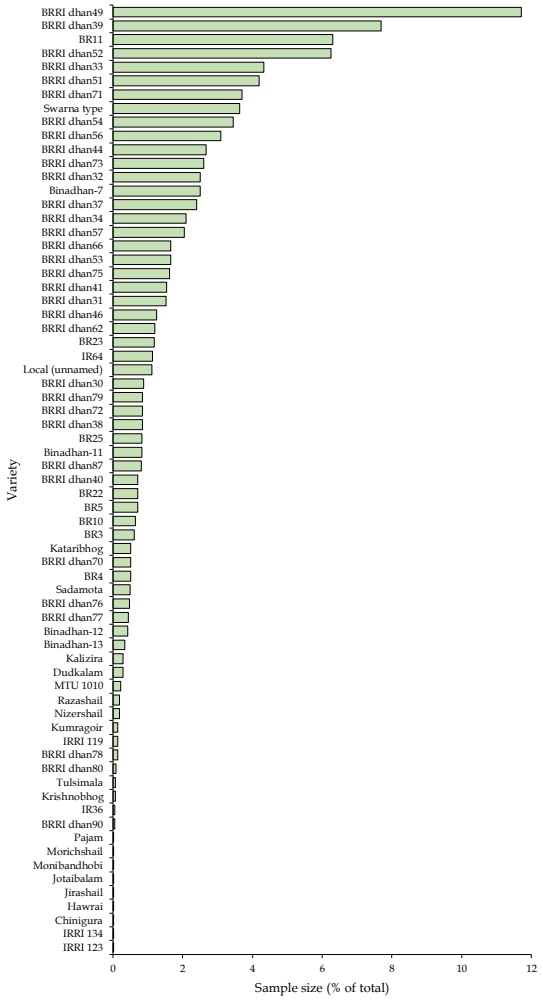

Fig. 3. Relative percentage of rice varieties accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season

BRRI dhan49 was the most tested variety, which accounted for 11.7% of the data. This was closely followed by BRRI dhan39 (7.7%), BR11 and BRRI dhan52 (6.3% each), BRRI dhan33 (4.3%), BRRI dhan51 (4.2%), BRRI dhan71 (3.7%), Swarna type (3.6%), BRRI dhan54 (3.5%) and BRRI dhan56 (3.1%). About 3.5% of meta-data accounted for low yielding varieties. As indicated earlier, BRRI dhan49 used in large numbers in the research field. Although not a variety of BRRI, Swarna type rice varieties used in a significant amount of research area that indicates the importance of the variety at farm level. The popularity (farmer accounted for 60%) of Swarna type variety was observed in another study (Parvin *et al.*, 2022).

Rice varieties accounted for in meta-data according to purpose of growing – Relative percentage of rice variety group

Absolute majority of the meta-data (86.2%) included High Yield Potential (HYP) category, which comprised of 43 varieties (Fig. 4). Only small proportion of data belonged to 'Aromatic' (7.4% data, 11 varieties), 'Photosensitivity' (5.4% data, 11 varieties) and 'Market Demand' (1.0% data, 4 varieties) category.

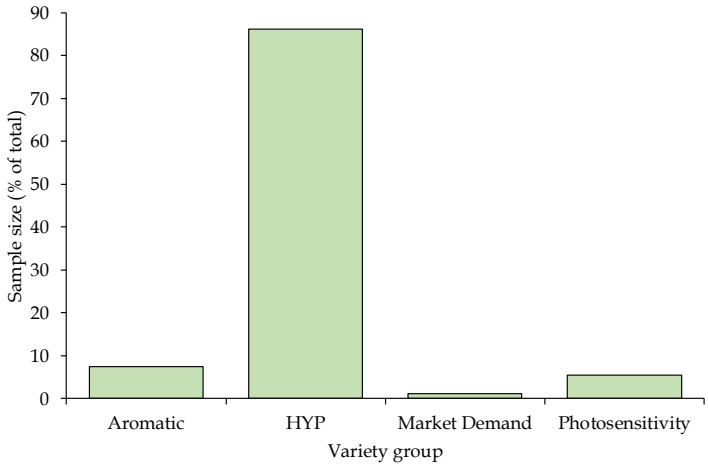

Fig. 4. Relative percentage of rice variety group (defined as 'purpose of growing') accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season

Rice varieties accounted for in meta-data according to purpose of growing – the distribution of yields

Fig. 5 presents the distribution of rice yields recorded in meta-data under the four categories of purpose of growing. The highest average yield was achieved from the HYP group (4.34 t ha^{-1}) followed by 'Market Demand' (3.88 t ha^{-1}) and 'Photosensitivity' (3.86 t ha^{-1}) and the lowest in the varieties under 'Aromatic' group (3.12 t ha^{-1}). Range of yield in the HYP varieties was 0.20 to 7.76 t ha^{-1} where the middle 50% of the yield data concentrated between 3.70 to 5.11 t ha^{-1}. On the other hand, the range of yield of 'Market Demand' varieties were 2.11 to 5.91 t ha^{-1} where middle 50% of the yield data concentrated between 3.11 to 4.73 t ha^{-1}. For the 'Photosensitivity' group, the range of yield was 0.03 to 6.75 t ha^{-1}, with the middle 50% of the yield data concentrated between 2.92 to 4.81 t ha^{-1}. Under the 'Aromatic' rice group, where the average yield was the lowest, the meta-data recorded the yield in the range of 0.38 to 5.94 t ha^{-1} with the middle 50% of the yield between 2.66 to 3.72 t ha^{-1}.

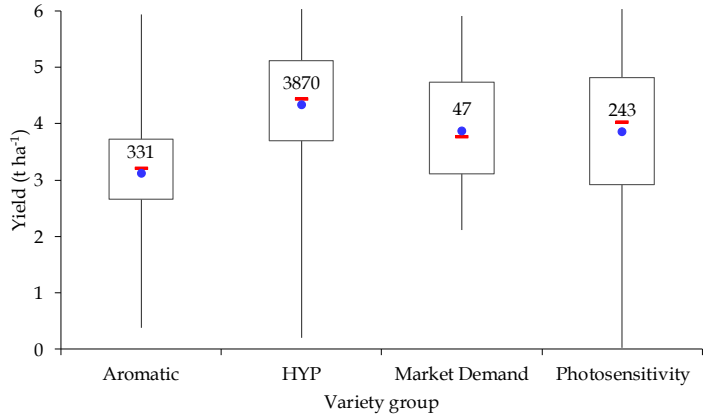

Fig. 5. Distribution of rice grain yield by variety group (defined as 'purpose of growing') accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season. Box represents middle 50% of the yields, vertical line is the range, and within the box, horizontal line is the median and solid circle is the average. Values inside the boxes denote for sample number within variety group. 'HYP' denotes for 'High Yield Potential'

Rice varieties accounted for in meta-data under 'High Yield Potential (HYP)' group - Relative percentage of the variety and yield distribution

Among the 43 varieties under the High Yield Potential (HYP)' group, the meta-data accounted for 13.6% of BRRI dhan49, 8.9% of BRRI dhan39, 7.3% of BR11 and BRRI dhan52, 5.0% of BRRI dhan33, 4.9% of BRRI dhan51, 4.3% of BRRI dhan71, 4.2% of Swarna type and 4.0% of BRRI dhan54 (Fig. 6). The rest 34 varieties, individually, accounted for < 4.0% in the composition of HYP group.

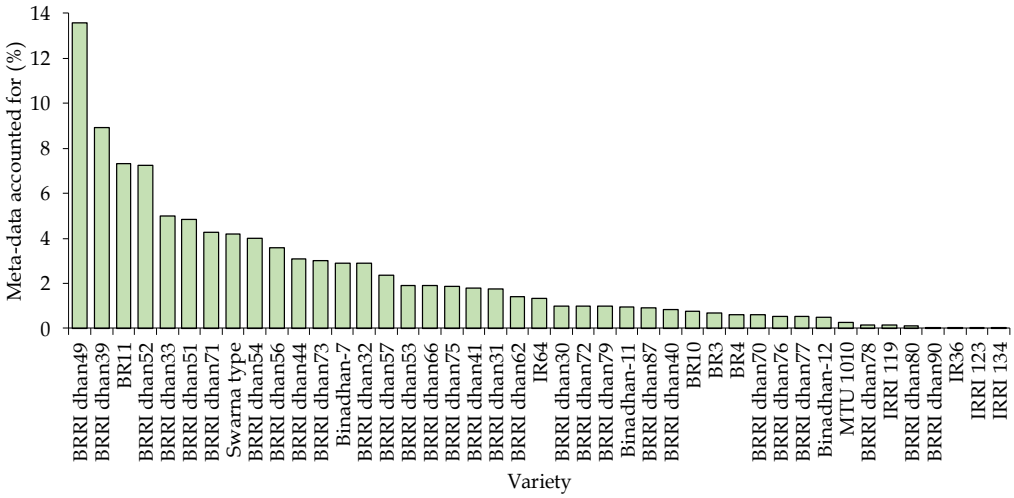

Fig. 6. Relative percentage of rice varieties under 'High Yield Potential (HYP)' group y group accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season

The yield resulted from the varieties listed in the Fig. 4, where it shows the newer varieties like BRRI dhan72, BRRI dhan79, BRRI dhan87, BRRI dhan76, BRRI dhan77, BRRI dhan78, BRRI dhan80, BRRI dhan90 produce higher yields (around 5 t ha^{-1}). Many varieties such as BR 10, BR 4, BRRI dhan49 and Swarna type produce yield close to 4.5 t ha^{-1}.

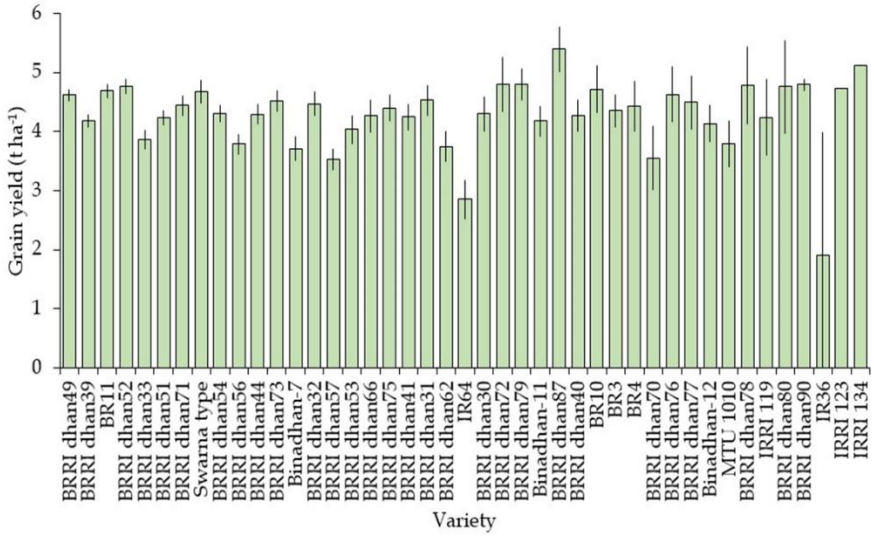

Fig. 7. Grain yield distribution of rice varieties under 'High Yield Potential (HYP)' group y group accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season

Rice grain yield distribution of BRRI dhan49 and Swarna type varieties accounted for in meta-data

Based on the farmers' inclination of adoption of Swarna type varieties (Parvin *et al.*, 2022), this section compares yields the top-ranked variety in meta-data, BRRI dhan49 with that of Swarna type. It was observed that both the varieties recorded almost similar maximum yield (7.76 t ha^{-1} in BRRI dhan49 and 7.55 t ha^{-1} in Swarna type). BRRI dhan49 produced the minimum yield of 0.38 t ha^{-1} and Swarna type produced 0.44 t ha^{-1} (Fig. 8). The Fig. 8 further shows that the middle 50% yield data of BRRI dhan49 and Swarna type was recorded between 4.09 to 5.36 t ha^{-1} and between 3.80 to 5.55 t ha^{-1}, respectively. The average yield of 4.62 t ha^{-1} was found from BRRI dhan49 and 4.67 t ha^{-1} from Swarna type. The median yield of 4.76 and 5.12 t ha^{-1} was received from BRRI dhan49 and Swarna type, respectively.

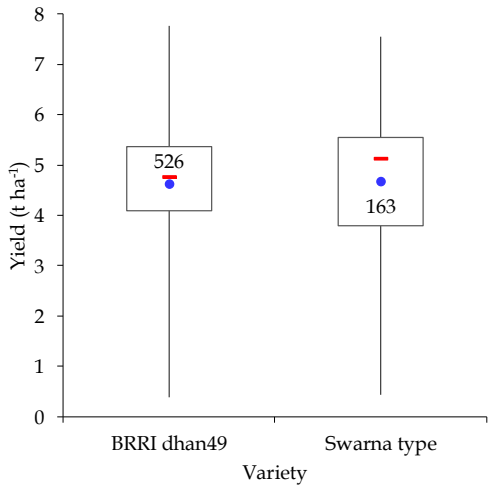

Fig. 8. Distribution of rice grain yield of BRRI dhan49 and Swarna type accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season. Box represents middle 50% of the yields, vertical line is the range, and

within the box, horizontal line is the median and solid circle is the average. Values inside the boxes denote for sample number within variety group.

Management in rice varieties

Three management aspects - transplanting time, seedling age, and hill density - are presented below.

Transplanting time

There was no significant trend in yield variation among the five-transplanting time (Fig. 9).

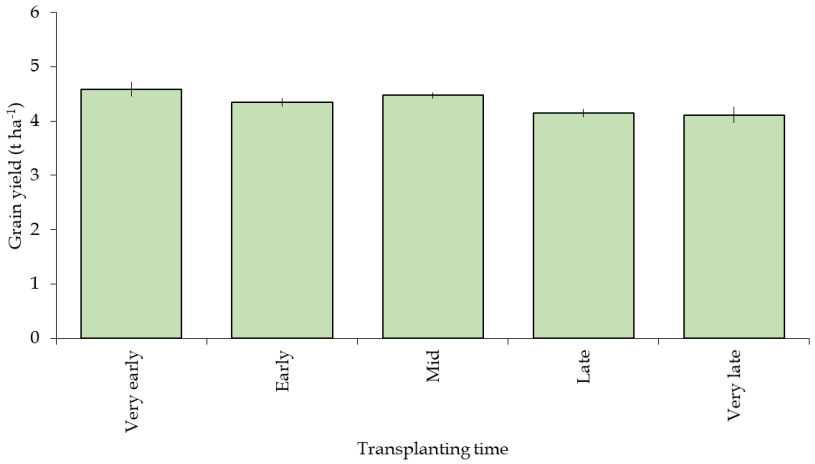

Fig. 9. Response of transplanting time across the varieties under High Yield Potential (HYP)' group accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season. Vertical bars represent 95% confidence intervals of the meta-data yields within each defined transplanting time window.

For BRRI dhan49, the average yield trend shows an increase from very early transplanting time to early transplanting time, then slowly decrease till the latest transplanting time. However, yields under the five transplanting time did not vary significantly (Fig. 10). For Swarna type, the average yield trend shows gradual decrease from early to late transplanting time, then slightly increased in very late transplanting time. The yield from late transplanting time (4.11 t ha^{-1}) was significantly lower than early (4.99 t ha^{-1}) or mid (4.89 t ha^{-1}) transplanting time, but not from the very late (4.30 t ha^{-1}). It may be noted that data for very early transplanting time was not available for this variety.

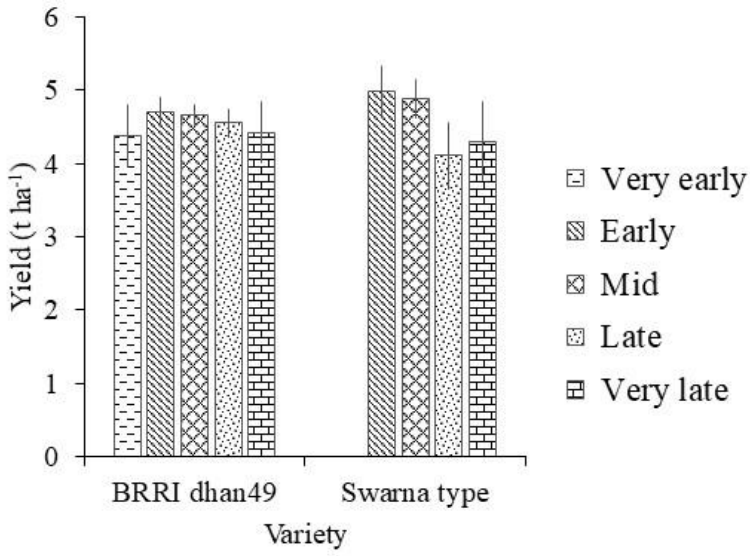

Fig. 10. Response of transplanting time on of BRRI dhan49 and Swarna type rice varieties accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season. Vertical bars represent 95% confidence intervals of the meta-data yields within each defined transplanting time window

Seedling age

Younger, middle aged and older seedlings produced statistically similar yield (Fig. 11).

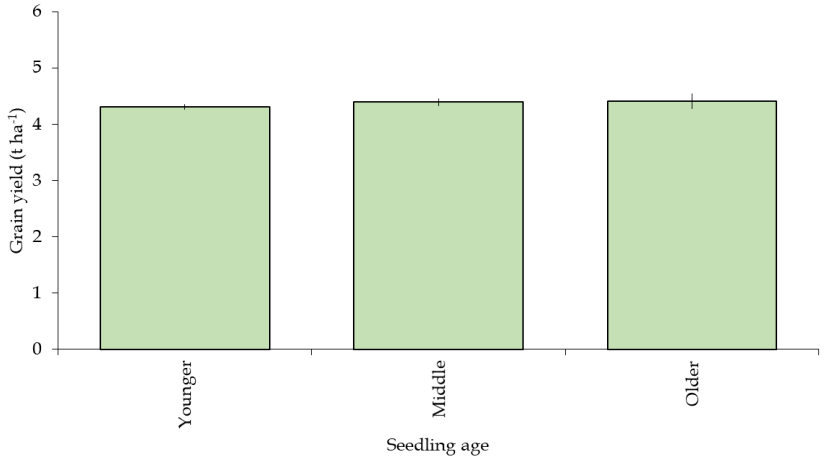

Fig. 11. Response of seedling age across the varieties under High Yield Potential (HYP)' group accounted for in meta-data in 10 years' research (2010 - 2019) during T. *Aman* season. Vertical bars represent 95% confidence intervals of the meta-data yields within each defined seedling age group

In BRRI dhan49, yield was the highest in older aged seedling (SA) group (5.13 t ha^{-1}), significantly higher than middle (4.48 t ha^{-1}) but not with younger SA group (4.64 t ha^{-1}) (Fig. 4.24). For Swarna type, the yield trend for SA groups was similar to BRRI dhan49. Across the SA groups under Swarna type, the yield differences were not significant (Fig. 12).

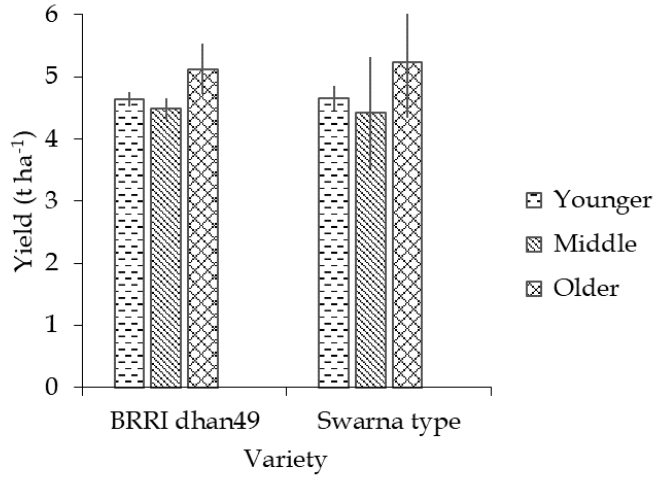

Fig. 12. Response of seedling age on of BRRI dhan49 and Swarna type rice varieties accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season. Vertical bars represent 95% confidence intervals of the meta-data yields within each defined seedling age group

Hill density

The very high hill density produced significantly higher yield than standard or high hill density (Fig. 13); difference of mean yield between standard and high hill density was not significant.

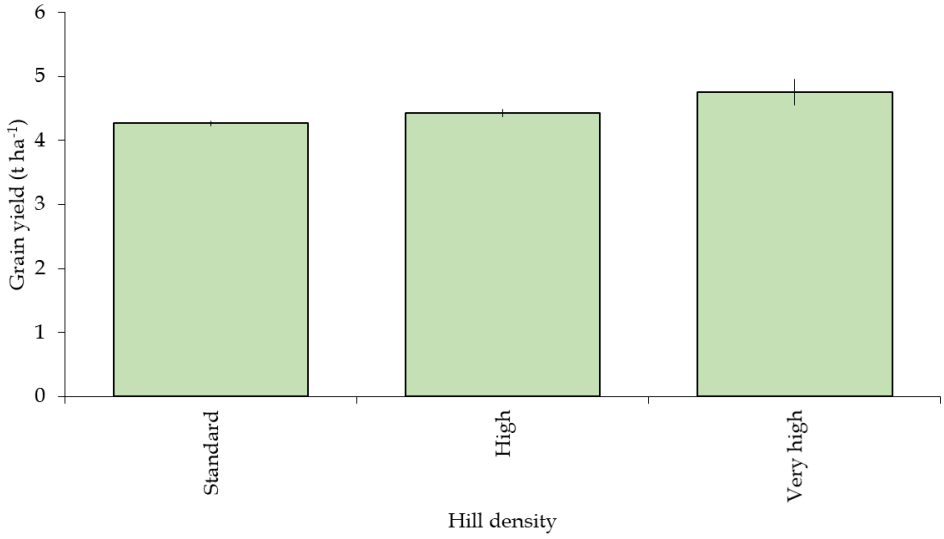

Fig. 13. Response of hill density across the varieties under High Yield Potential (HYP)' group accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season. Vertical bars represent 95% confidence intervals of the meta-data yields within each defined hill density group.

The yield in both varieties increased with increase in hill density (standard, high and very high) (Fig. 14). The yield differences in BRRI dhan49 due to hill density were not significant. On the other hand, in Swarna type the yield in very high hill density was significantly higher than high or standard hill density, with no statistical difference between high or standard hill densities.

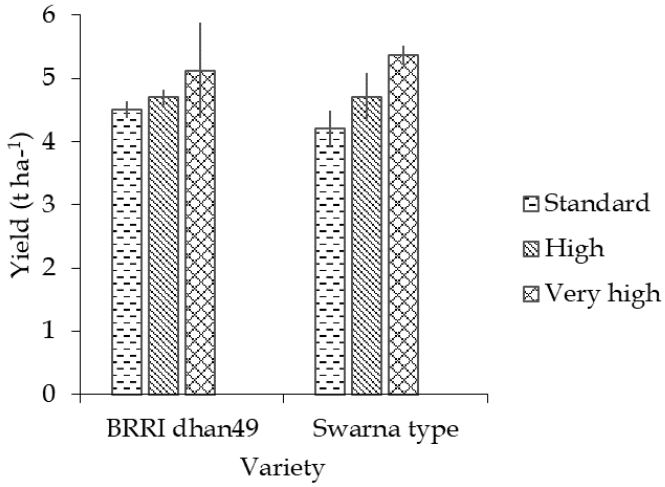

Fig. 14. Response of hill density on of BRRI dhan49 and Swarna type rice varieties accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season. Vertical bars represent 95% confidence intervals of the meta-data yields within each defined hill density group.

Environmental response of rice varieties

The meta-analysis showed average yield varies between years of experimentations, for example Fig. 15. Yield in 2017 was significantly lower and yield in 2018 was significantly higher compared to other years. Yield also varied between the locations, for example yield was significantly high in Dinajpur, Jamalpur, Jhalokathi, Habiganj, Kushtia and Thakurgaon compared to low yield in Joypurhat, Bogura. (Fig. 16).

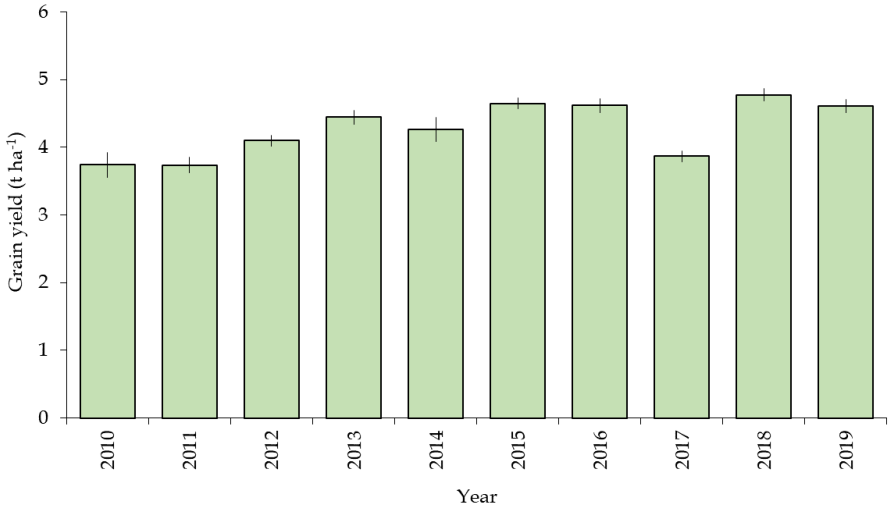

Fig. 15. Spread of rice yield, year-by-year, across the varieties under High Yield Potential (HYP)' group accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season. Vertical bars represent 95% confidence intervals of the meta-data yields within each defined year

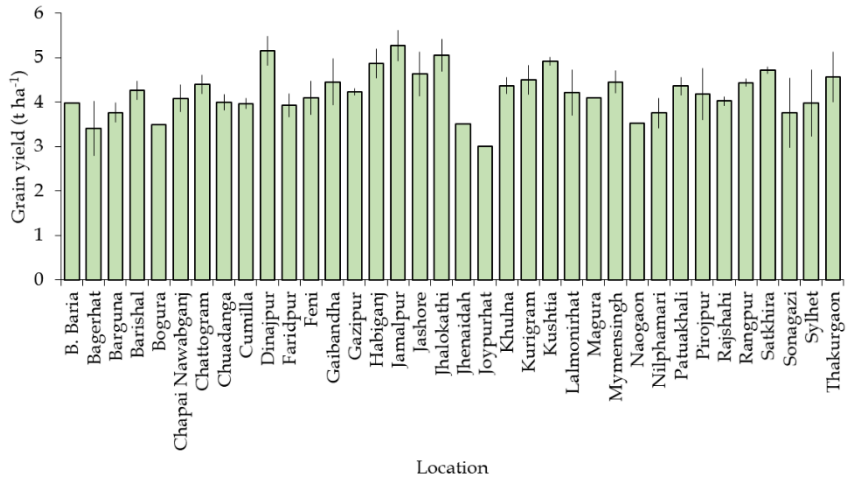

Fig. 16. Spread of rice yield, location-by-location, across the varieties under High Yield Potential (HYP)' group accounted for in meta-data in 10 years research (2010 - 2019) during T. *Aman* season. Vertical bars represent 95% confidence intervals of the meta-data yields within each defined location.

For BRRI dhan49, the high (=> 5 t ha^{-1}) and second high (4 to < 5 t ha^{-1}) yields spread across the locations (designated as districts) and years (Fig. 17). The presence of moderate yields (3 to < 4 t ha^{-1}) was dominantly observed across the years in two locations - Rangpur and Cumilla, whereas low yields (< 3 t ha^{-1}) were recorded only during 2015 in Lalmonirhat, Nilphamari and Sylhet. The 2015 was the year when the yield variability observed across the four yield gradients, depending on locations.

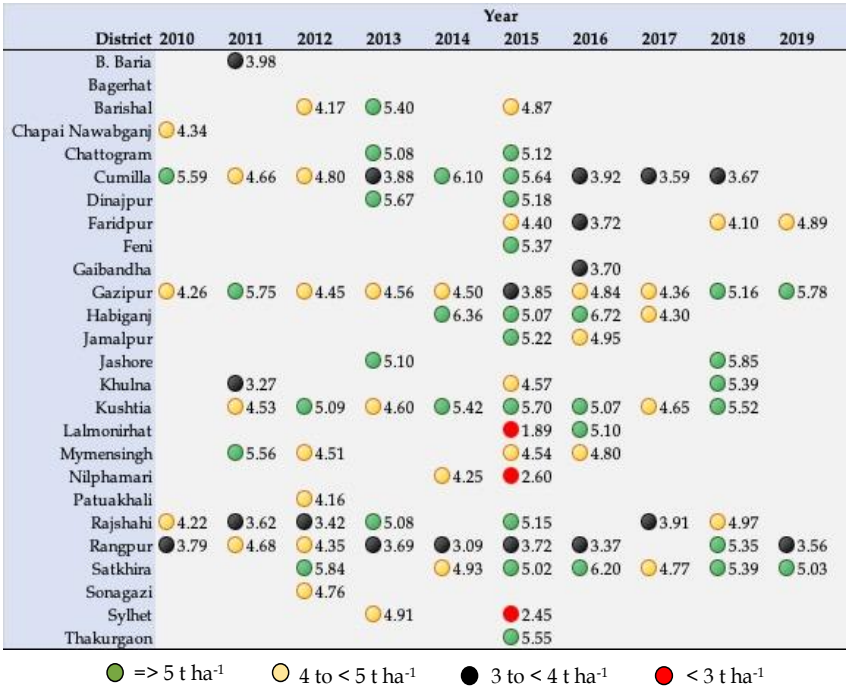

Fig. 17. Spread of rice yield of the variety 'BRRI dhan49' across the environments (matrix of location (district) and season (year) designated in the meta-data sources. This is a compilation of 526 data-points. Number within a cell in the figure denotes for average of a yield for the matrix. The filled circles represent yield gradient as expressed in the legend.

For Swarna type, the high (=> 5 t ha^{-1}) yields spread across locations during 2013 to 2017 (no data were available for 2014) (Fig. 18). The presence of the second high (4 to < 5 t ha^{-1}) yields was very limited, whereas the moderate yields (3 to < 4 t ha^{-1}) were recorded across wider locations and years. On the other hand, low yields (< 3 t ha^{-1}) were reported in three scenarios - Kushtia in 2011, Rajshahi in 2012 and Rangpur in 2019.

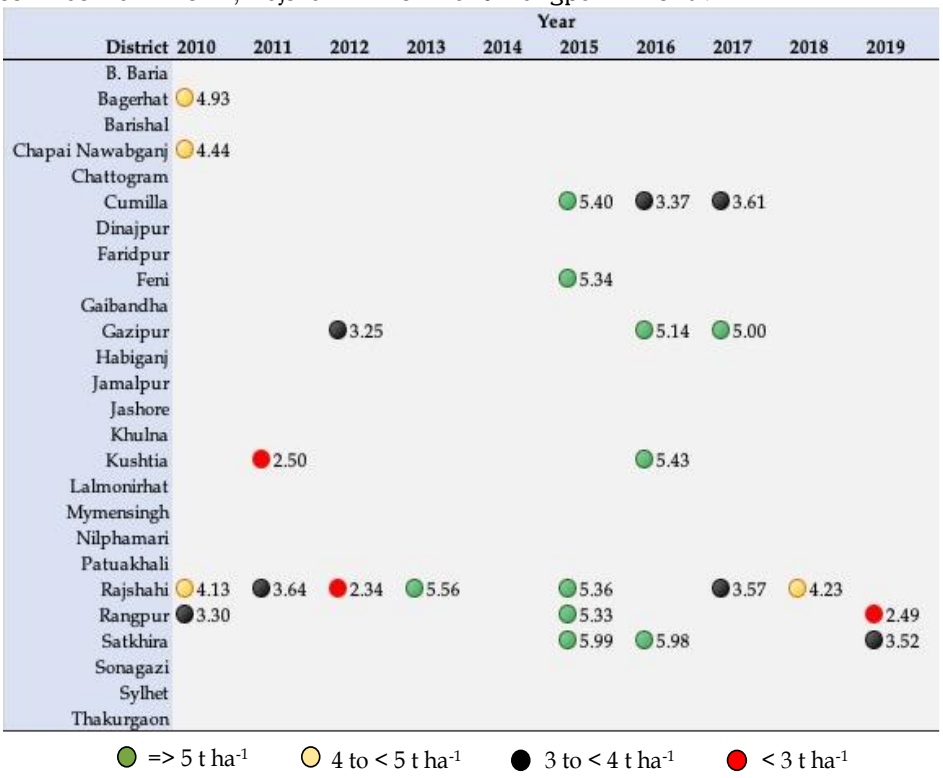

Fig. 18. Spread of rice yield of the variety 'Swarna type' across the environments (matrix of location (district) and season (year) designated in the meta-data sources. This is a compilation of 163 data-points. Number within a cell in the figure denotes for average of a yield for the matrix. The filled circles represent yield gradient as expressed in the legend.

Conclusion

The meta-analysis shows the yield potential is not solely dependent on varietal category, environmental adaptation and optimized management practices are also crucial. The results provide a clear message to stakeholders that variety-environment-management synchronized approach is essential for improved yields of T. *Aman* rice in Bangladesh.

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