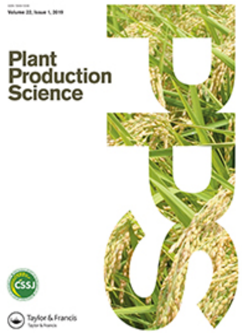

Plant Production Science

ISSN: 1343-943X (Print) 1349-1008 (Online) Journal homepage: https://www.tandfonline.com/loi/tpps20

Development of hand tractor-mounted seed drill for rice-based cropping systems in the Philippines

Elmer G. Bautista, Eden C. Gagelonia, John E. Abon, Aurora M. Corales, Crisanta S. Bueno, Niño P.M.C. Banayo, Roman V. Lugto, Roel R. Suralta & Yoichiro Kato

To cite this article: Elmer G. Bautista, Eden C. Gagelonia, John E. Abon, Aurora M. Corales, Crisanta S. Bueno, Niño P.M.C. Banayo, Roman V. Lugto, Roel R. Suralta & Yoichiro Kato (2019) Development of hand tractor-mounted seed drill for rice-based cropping systems in the Philippines, Plant Production Science, 22:1, 54-57, DOI: 10.1080/1343943X.2018.1562309

To link to this article: https://doi.org/10.1080/1343943X.2018.1562309

Published online: 07 Jan 2019.

PLANT PRODUCTION SCIENCE
2019, VOL. 22, NO. 1, 54–57
https://doi.org/10.1080/1343943X.2018.1562309

SHORT REPORT

OPEN ACCESS Check for updates

Development of hand tractor-mounted seed drill for rice-based cropping systems in the Philippines

Elmer G. Bautista[a], Eden C. Gagelonia[a], John E. Abon[a], Aurora M. Corales[a], Crisanta S. Bueno[b], Niño P.M. C. Banayo[b], Roman V. Lugto[c], Roel R. Suralta[a] and Yoichiro Kato[b,d]

[a]Philippine Rice Research Institute, Nueva Ecija, The Philippines; [b]International Rice Research Insitute, Laguna, The Philippines; [c]VAL Agri-Machinery, Nueva Ecija, The Philippines; [d]Institute for Sustainable Agro-ecosystem Services, The University of Tokyo, Tokyo, Japan

ABSTRACT

Dry direct-seeded rice is widely practiced in drought-prone environments in tropical Asia where mechanized options for crop establishment are in great demand. The objective of this study is to identify the suitable design of a hand tractor-mounted multigrain seed drill under biophysical conditions in the Philippines. The prototype was newly designed and tested under field conditions in three provinces in 2015 and 2016. The results suggested that the prototype with tined furrow openers and an inclined circular seed plate in the hopper for seed metering driven by the ground wheel through the combination of chain and sprocket produced rice grain yield similar to the crop established from broadcasting. Field experiments also confirmed that the seed drill has a capacity of over 2 ha day^{-1} for rice and over 3 ha day^{-1} for mung bean, and thus, the prototype appears promising for rainfed lowlands in the Philippines.

Abbreviations: BS: broadcast seeding; FS: furrow seeding; IRRI: International Rice Research Institute; MSD: Multigrain seed drill; PhilRice: Philippine Rice Research Institute

ARTICLE HISTORY
Received 7 November 2018
Revised 2 December 2018
Accepted 13 December 2018

KEYWORDS
Direct-seeded rice; farm mechanization; rainfed lowland; seeding rate; two-wheel tractor

Introduction

Rainfed lowlands in the Philippines have a total of 1.49 million ha, accounting for 36% of the country's total rice area. Rice is the only crop that can be well grown during wet seasons due to waterlogging in lowland fields. On the other hand, dryland crops such as maize and mung bean are often grown during dry seasons depending on the availability of supplemental irrigation.

Majority of farmers in tropical Asia practice manual rice transplanting. However, unreliable water supply often causes delay in transplanting and resultant use of aged seedlings causes huge yield losses in rainfed lowlands (Haefele et al., 2016). To address the risk of crop failure due to drought, dry direct seeding technology spreads in the water-scarce rice areas (Sansen et al., in press). Some farmers manually dibble or sow seeds on the shallow ditches to secure crop establishment. Others, on the other hand, broadcast dry seeds to save labor required for sowing despite risk of poor establishment (Kato & Katsura, 2014; Ohno et al., 2018).

Mechanized dry direct seeding is an option to address the above problems while saving labor for crop planting. Development of hand tractor-mounted seed drills may contribute to the reduction of production cost compared with a manual dibbling method and improve crop establishment compared with a manual broadcasting method. Commercial seed drills are available in other countries in Southeast Asia, but there is no multigrain seed drill (MSD) locally available for Philippine farmers. Since the use of four-wheel tractors is still a costly option for resource-poor communities, a seed drill mounted on two-wheel tractors, which can be fabricated and repaired by local manufacturers, must be designed (Bakker et al., 2002). The objective of this study is to identify a suitable design of a compact seed drill mounted on two-wheel tractors widely available in the Philippines that can be used for rice and other high-valued crops such as maize and mung bean.

Materials and methods

Design of prototypes of seed drill mounted on two-wheel tractors

A prototype of four-row seed drills (spacing 20 cm between rows) with tined furrow openers and an inclined circular seed plate in the hopper was designed

CONTACT Yoichiro Kato ykato@isas.a.u-tokyo.ac.jp

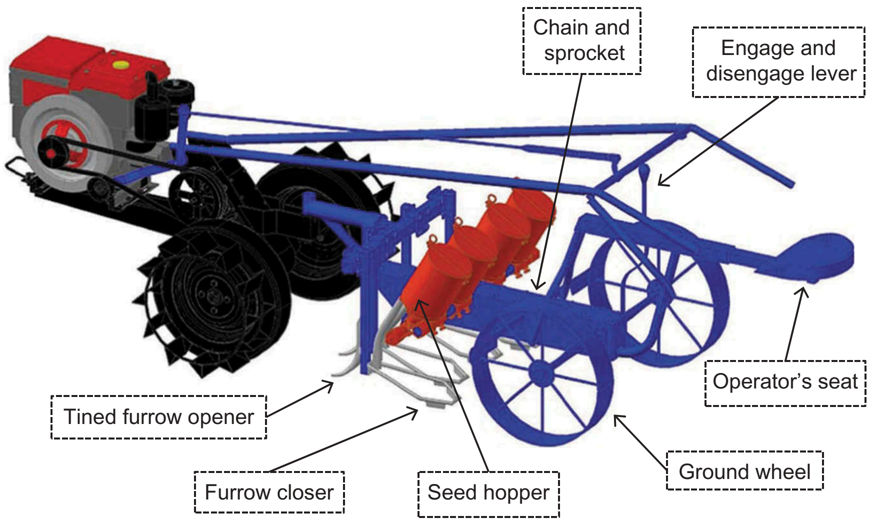

Figure 1. The prototype of a multigrain seed drill designed at the Philippine Rice Research Institute. The prototype had a ride-on attachment to a two-wheel tractor, a built-in furrow opener and closer, an inclined circulating replaceable seed plate (for seed metering), and seed hopper made of plastic containers. The seed metering was driven by ground wheels through chain and sprocket combination with the provision of engaged and disengaged lever. The furrow opener was positioned in one line. The chain and sprocket drives, which were simplified into a single-stage conversion, were covered with metal plates to protect it from dust during operation and avoid chain damage. The bevel gears were added to rotate the drive shift of seeding plate from the ground wheel.

at the Philippine Rice Research Institute (PhilRice), Nueva Ecija in March 2016, by referring to the previous agricultural engineering studies on seed drills (IRRI, 1986) (Figure 1).

To adjust the seeding rate to our target, different seed plates were tested for rice, maize, and mung bean seeds in the laboratory of PhilRice in April 2016. Metering plates having four and eight holes (10.0 and 12.5 mm diameter) were compared. The seed drills were jacked-up and the drive wheel was rotated 10 times. A plastic bag was placed on the discharge chute to collect the dropped seeds when turning the wheels. The weight of seeds dropped; weight of damaged seeds due to machine, number of turns of drive wheel, and wheel diameter were measured; then, the seeding rates and percent damage seeds were calculated.

Agronomic performance of dry direct-seeded rice with the seed drill

Field experiments were conducted in three locations in the Philippines during the wet season of 2016; at the lowland farms of PhilRice Central Experiment Station, Nueva Ecija (15°40′ N, 120°53 E), of the Batac research station of PhilRice, Ilocos Norte (18°05′ N, 120°54 E), and of the Pangasinan State University, Sta. Maria, Pangasinan (15°95′ N, 120°68 E). The topsoil (0–20 cm) was loam in Nueva Ecija (clay 20%, silt 42%, sand 38%), clay in Ilocos Norte (clay 41%, silt 40%, sand 19%), and silt loam in Pangasinan (clay 17%, silt 76%, sand 7%). Rice seeds (cv. NSIC Rc 348) were sown on non-puddled and unsaturated soil on 14–21 June 2016. Four treatments were arranged in randomized complete block design with four replicates: (1) seeding by the prototype of a compact seed drill with a row spacing of 20 cm (hereafter, MSD); (2) seeding by manually creating furrows with a row spacing of 20 cm, followed by manual seeding at a rate of 60 kg ha^{-1} (hereafter, furrow seeding; FS60); (3) manual broadcasting of seeds at a rate of 60 kg ha^{-1} (hereafter, broadcast seeding; BS60); and (4) broadcast seeding at a rate of 150 kg ha^{-1} (BS150). Furrows were created in FS60 using a furrow opener attached to a four-wheel tractor. Covering of seeds was done with the use of comb harrow attached to a two-wheel tractor for the plots of FS60, BS60, and BS150. The size of each plot was 1000 m^2. Total inputs of N, P_2O_5, and K_2O were 100, 40, and 40 kg ha^{-1}, respectively. The total amount of rainfall during the experiments (June–October) recorded at the meteorological stations at the sites was 1346 mm in Nueva Ecija, 2292 mm in Ilocos Norte, and 2708 mm in Pangasinan. Although rice crop was grown under rainfed condition, no symptom of drought injury was observed at any site.

The performance of the seed drill was evaluated; the actual travelling speed, the operating hours per unit area, and the weight of seeds sown were measured to calculate the seeding rate and field capacity. The number of emerged seedlings and seeding depth were measured for four 0.1-m^2 quadrats (0.5 m × 0.2 m) or one 0.5 m-row for MSD and FS plots and four 0.25-m^2 quadrants (0.5 m × 0.5 m) for BS60 and BS150 in each plot at 20 days after sowing. At maturity, the number of panicles was counted and grain yield was measured from two 5.0-m^2 quadrats (2.0 m × 2.5 m) in each plot, avoiding border rows. All harvested panicles were threshed and winnowed to determine grain yield, expressed at a 14% grain moisture level. Data were analyzed in the open-access software for statistical analysis (IRRI, 2014), which is implemented in the R statistical package (R Core Team, 2013).

Results and discussion

Design and evaluation of prototypes of seed drill mounted on two-wheel tractors

The prototype showed that the seeds were delivered at constant proportion under field conditions. Seedling emergences of rice, mung bean, and maize were 33 plants per linear meter (165 plants m^{-2}), 26 plants per linear meter (43 plants m^{-2}), and 4 plants per linear meter (6.7 plants m^{-2}), respectively. The average forward speed was found at 3.50 km h^{-1}, and the seed drill had a theoretical field capacity (an 8-h day) of 2.24 ha day^{-1} for rice and 3.36 ha day^{-1} for mung bean and maize.

Different seed plates were compared using the seeds of rice, maize, and mung bean in the laboratory. The seed plate with eight holes at 10 mm diameter provided targeted seeding rates for mung bean and rice; the one with eight holes at 12.5 mm diameter provided a targeted rate for maize (Table 1). High percentage of damaged seeds was recorded for rice in all seed metering plates because of the clearance between base and seed plates, indicating that clearance of plates should be less than 1.0 mm to avoid insertion of small seeds in between.

Field experiments: agronomic performance of dry direct-seeded rice

The seeding rate was 30 kg ha^{-1} using the seed metering plate with eight holes at 10 mm diameter in Pangasinan, while the seeding rate was 58 kg ha^{-1} in Nueva Ecija and 48 kg ha^{-1} in Ilocos Norte where the seed metering plate with eight holes at 12.5 mm diameter was used. Compared with the potential seeding rate detected in the laboratory (Table 1), only 62–76% of rice seeds were sown. The seed drill performed at average field capacity of 0.26 ha h^{-1} in Pangasinan, 0.28 ha h^{-1} in Nueva Ecija, and 0.25 ha h^{-1} in Ilocos Norte.

The seeding depth in MSD ranged from 15.8 to 31.5 mm, while from 16.9 to 27.0 mm in FS60, and from 15.7 to 22.9 mm in BS60 or BS150 (Table 2). Variation in the seeding depth in MSD was attributable to the condition of seedbed preparation, particularly the tillage depth. In Pangasinan, stubbles and residue of the previous crop were accumulated in between the furrow openers. Thus, the furrow openers were intently raised to avoid the residue, and as a result, seeding depth became shallower. The

Table 2. Seeding depth, seedling number, panicle number, and grain yield in four different methods of dry direct-seeded rice in the Philippines in the wet season of 2016.

Province	Treatment	Seeding depth (mm)	Emerged seedlings (m^{-2})	Panicles (m^{-2})	Grain yield (t ha^{-1})
Pangasinan	MSD	15.8^{c}	35^{a}	207	3.14
	FS60	27.0^{a}	191^{b}	300	3.66
	BS60	19.7^{bc}	134^{b}	259	3.75
	BS150	22.9^{ab}	266^{c}	342^{NS}	3.37^{NS}
Nueva Ecija	MSD	31.5^{a}	169^{a}	273^{a}	2.67
	FS60	16.9^{b}	142^{a}	290^{ab}	2.66
	BS60	16.3^{b}	130^{a}	280^{a}	2.19
	BS150	15.7^{b}	316^{b}	375^{b}	2.34^{NS}
Ilocos Norte	MSD	21.1^{a}	88^{a}	211	2.82
	FS60	20.4^{a}	138^{ab}	267	2.85
	BS60	15.9^{b}	120^{a}	245	2.99
	BS150	17.8^{ab}	196^{b}	255^{NS}	2.91^{NS}

MSD: Multigrain seed drill; FS60: furrow seeding at a seeding rate of 60 kg ha^{-1}; BS60: broadcast seeding at a seeding rate of 60 kg ha^{-1}; BS150: broadcast seeding at a seeding rate of 150 kg ha^{-1}. Different letters indicate significant difference at 5% probability. NS: Not significant.

Table 1. Effects of different size of holes in the seed metering plate on the seeding rate and the percentage of damaged seeds in a multigrain seed drill in the laboratory test at the Philippine Rice Research Institute.

	Seeding rate (kg ha^{-1})			Damaged seeds (%)		
Size of holes	Mung bean	Rice	Maize	Mung bean	Rice	Maize
8 mm diameter, 8 holes	5.3^{d}	17.5^{d}	NA	6.2^{c}	12.7^{c}	NA
10 mm diameter, 4 holes	11.6^{c}	17.6^{c}	NA	7.1^{a}	9.7^{d}	NA
10 mm diameter, 8 holes	19.4^{b}	39.6^{b}	1.3^{b}	6.3^{b}	19.6^{b}	1.3^{b}
12.5 mm diameter, 8 holes	44.6^{a}	77.3^{a}	27.7^{a}	1.0^{d}	23.6^{a}	3.8^{a}

Varieties: "Rough" and "Shiny" for mung bean, "NSIC Rc348" for rice, and "Pioneer 4097" for maize. NA: Not available. Different letters indicate significant difference at 5% probability.

number of established seedlings greatly varied among the treatments and sites and was significantly correlated with panicles m^{-2} ($r = 0.927$, $p < 0.01$, $n = 12$). Grain yield was not significantly different between the treatments in any location, although yield advantage of the use of seed drills over manual broadcast seeding has been often reported in dry direct-seeded rice on sandy soils (Sansen et al., in press; Xangsayasane et al., 2019). As compact seed drills have limited residue-handling capability (Bakker et al., 2002), seedbed preparation for mechanized dry direct seeding on fine-textured soils requires further study to minimize clogging problems.

In conclusion, this study successfully identified the suitable prototype of hand tractor-mounted seed drill for rainfed lowlands in the Philippines. With locally available two-wheel tractors, the newly designed seed drill performed well for dry direct-seeded rice, maize, and mung bean, showing the acceptable field capacity with more than 2 ha day^{-1}.

Acknowledgment

The authors acknowledged Mr. Roman Riñen, Mr. Jay-ar Tapec, Dr. Ricardo Garcia, Mr. Silvestre Briones, Mr. Royette Santos, and Mr. Edward Fernandez for their support.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

We are grateful for financial support from the International Fund for Agricultural Development (IFAD) for the Consortium for Unfavorable Rice Environments (CURE), the Bureau of Agricultural Research under the Department of Agriculture (DA-BAR), the Philippines, and a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (JSPS): (Grant Number 18KK0169).

References

Bakker, R. R., Bell, M. A., & Rickman, J. F. (2002). Mechanization issues in tillage and crop establishment for dry direct-seeded rice. In S. Pandey, M. Mortimer, L. Wade, T. P. Tuong, K. Lopez, & B. Hardy (Eds.), *Direct seeding: Research issues and opportunities. Proceedings of the international workshop on direct seeding in asian rice systems: Strategic research issues and opportunities, 25–28 Jan 2000, Bangkok, Thailand* (pp. 219–230). Los Baños, Philippines: International Rice Research Institute.

Haefele, S. M., Kato, Y., & Singh, S. (2016). Climate ready rice: Augmenting drought tolerance with best management practices. *Field Crops Research*, *190*, 60–69.

International Rice Research Institute. (1986, September 2–6). Small farm equipment for developing countries. In: *Proceedings of the international conference on small farm equipment for developing countries: Past experiences and future priorities* (pp. 629). Los Banos, The Philippines.

IRRI. (2014). Statistical tool for agricultural research (STAR) v. 2.0.1. Retrieved October 15, 2018, from http://bbi.irri.org

Kato, Y., & Katsura, K. (2014). Rice adaptation to aerobic soils: physiological considerations and implications for agronomy. *Plant Production Science*, *17*, 1–12.

Ohno, H., Banayo, N. P., Bueno, C., Kashiwagi, J., Nakashima, T., Iwama, K., … Kato, Y. (2018). On-farm assessment of a new early-maturing drought-tolerant rice cultivar for dry direct seeding in rainfed lowlands. *Field Crops Research*, *219*, 222–228.

R Core Team. (2013). R: A language and environment for statistical computing. R foundation for statistical computing. Vienna, Austria. Retrieved October 15, 2018, from http://www.R-project.org

Sansen, K., Wongboon, W., Jairin, J., & Kato, Y. (2019). Farmer-participatory evaluation of mechanized dry direct-seeding technology for rice in northeastern Thailand. *Plant Production Science*, 22(1), 46-53.

Xangsayasane, P., Phongchanmisai, S., Vuthea, C., Ouk, M., Bounphanousay, C., Mitchell, J., & Fukai, S. (2019). A diagnostic on-farm survey of the potential of seed drill and transplanter for mechanised rice establishment in central Laos and southern Cambodia. *Plant Production Science*, *22*(1), 12–22.