MECHANIZED DRY DIRECT SEEDING using the Multipurpose Seeder

THE RIPE OPTION

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December 2022

We are a government corporate entity (Classification E) under the Department of Agriculture. We were created through Executive Order 1061 on 5 November 1985 (as amended) to help develop high-yielding and cost-reducing technologies so farmers can produce enough rice for all Filipinos.

With our “Rice-Secure Philippines” vision, we want the Filipino rice farmers and the Philippine rice industry to be competitive through research for development work in our central and seven branch stations, coordinating with a network that comprises 60 agencies strategically located nationwide.

We have the following management certifications: ISO 9001:2015 (Quality) and ISO 14001:2015 (Environmental).

Mailing address: Maligaya, Science City of Muñoz, 3119 Nueva Ecija
E-mail: prri@philrice.gov.ph
Home page: www.philrice.gov.ph

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And finally, we thank God Almighty for allowing us to do this important project, which is our humble contribution to agricultural development in this country.

FOREWORD

Climate change is among the biggest "wicked issues" in rice cultivation. From the literature, we know that wicked problems are difficult to solve owing to the extent of the interconnectedness of issues attached to them. With climate change, we know that water will be scarce for agriculture, if not already, given its competition with more urgent and important concerns such as for domestic purposes. We also know that the workforce is abandoning the agriculture sector in favor of the more established income-generating industries. The recitation of related issues can go on.

It is for this reason that thinkers in the agriculture sector are innovating to come up with solutions so farmers may continue cultivating crops despite the scenarios cited above.

This book revolves around the mechanized dry direct seeding (MDDS) technology project of DA-PhilRice and UPLB funded by the DA-Bureau of Agricultural Research. In rice cultivation, this technology is known to be more cost-effective than transplanting owing primarily to reduction in labor cost.

There are, however, difficulties surrounding dry direct seeding such as the inadequacy of workforce during crop establishment and inferior crop establishment itself. This book discusses in detail the MDDS technology—its advantages over manual dry direct seeding and manual transplanting. It gives extension workers and intermediaries, and progressive farmers themselves adequate information as to why MDDS is now the big thing in rice crop establishment.

The Multi-Purpose Seeder, which is the main machine featured in this book, is adaptable not only to rice but also corn and mungbean.

This publication also benefits researchers, students, members of the academe, and policy conduits in the agriculture sector. Data from field work are put together in this book to invite productive discourses on the optimization of the MP Seeder for dry direct seeding.

John C. de Leon

Executive Director

DA-PhilRice

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AFMECH	Agriculture and Fishery Mechanization
AMMDA	Agricultural Machinery Manufacturers and Distributors Association
AMTEC	Agricultural Machinery Testing and Evaluation Center
BMP	Best Management Practices
CAR	Cordillera Administrative Region
DA-RFO	Department of Agriculture-Regional Field Office
DAS	Day After Seeding
DP	Drought-Prone
DS	Dry Season
FOB	Fairness Opinion Board
FOR	Fairness Opinion Report
FP-FV	Farmer's Practice-Farmer's Variety
FR	Favorable Rainfed
HP	Horsepower
IP	Intellectual Property
IPB	Institute of Plant Breeding
IPOPHIL	Intellectual Property Office of the Philippines
kg/ha	kilogram per hectare
LGU	Local Government Unit
LARES	Lipa City Agricultural Research and Extension Station
MAO	Municipal Agriculture Office
MDDS	Mechanized Dry Direct Seeding
MMSU	Mariano Marcos State University
MP Seeder	Multi-Purpose Seeder
MP-FV	MP Seeder-Farmer's Variety
MP-SU	MP Seeder-Sahod Ulan
NEXTGEN	Next-Generation Rice Varieties
NSIC	National Seed Industry Council
OPV	Open-pollinated Variety
PAES	Philippine Agricultural Engineering Standards
PCAARRD	Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development
PI	Panicle Initiation
QARES	Quezon Agricultural Research and Extension Station
SCRC	Southern Cagayan Research Center
t/ha	ton per hectare
TE	Tail-end
UPLB	University of the Philippines Los Baños
WS	Wet season


RD 90N
MP SEEDER
PHOTO BY REMD

1

MECHANIZED SEEDING TECHNOLOGY: Improving crop productivity and increasing income in rice-based rainfed and water-scarce environments in the Philippines

INTRODUCTION

Mechanized dry direct seeding method addresses problems of high labor cost, water scarcity, and crop failure after delayed monsoon rains. The research for this book supports the Research and Development Agenda of the Department of Agriculture-Bureau of Agricultural Research pertaining to ensuring food security for the Philippines. The Multi-Purpose Seeder project aims to boost yield, reduce crop establishment cost, and increase net income of farmers in rice-based areas by developing the mechanized dry direct seeding (MDDS) technology package.

Benefits from using the MP Seeder are not confined to rice production in rice-based areas. It can also be used to seed other crops, thereby promoting crop diversification. Smallholder farmers in rice-based areas still manually seed high-value crops like corn because there is no option for appropriate mechanized seeding. The practice is time-consuming and uniformity of crop stand during emergence is not assured. MP Seeder is applicable to rice and high-value crops, and can enable farmers to plant in a timely manner in combination with best management practices, thereby improving their crop production.

Focusing not only on rice but also on high-value crops would be a good strategy to promote the use of MP Seeder. Oftentimes farmers are reluctant to take risks in the cultivation of staple food crops, and they hardly accept any drastic change in their management practices. However, the financial gains that can be derived from efficient establishment of high-value crops and the convenience of mechanical seeding may prove as adequate reasons for farmers to believe in the MP Seeder.

This book is divided into four chapters that present the four major milestones of the project. Chapter 2 discusses the work done on developing best management practices in MDDS for rice, corn, and mungbean using the MP Seeder. Specifically, it details three banner activities: (1) identification of management options for improving crop establishment under dry direct seeding; (2) identification of best nutrient and weed management packages for MDDS technology; and (3) summary of existing developed technologies for corn and mungbean.

Chapter 3 covers the work done to verify the technologies developed and presented in Chapter 2. It describes the verification trials for rice, corn, and mungbean using the best management practices developed in the project. The key activities conducted in the trials were field comparison of MDDS and current farmers' practices, and quantification of productivity and income gains in using MDDS.

Chapter 4 tackles the engineering component of the project, which is the development of MP Seeder plus. The key activities are the adjustment of MP Seeder, adjustment of MP Seeder plus options (fertilizer hopper and weeder) in rainfed and tail-end irrigated areas in the regions, development of options for optimum tillage, and capacity building for accredited local manufacturers.

Chapter 5 characterizes the dissemination strategies and development of pathways for uptake of the MDDS technology. Specifically, this chapter delves into activities for scaling out, identification of opportunities and challenges of MDDS technology, and capacity-building and training programs.

Dry seeding of rice: Wisdom of drought adaptation from the past

Addressing issues on labor shortage during crop establishment and the unpredictable onset of monsoon rains to saturate soil in preparation for soil puddling are the two major challenges in rainfed areas not only here in the Philippines but also in other Asian countries. The lack of early rains delays planting or causes the planting of overaged and yellowish seedlings, inevitably resulting in large yield losses. It often causes the cessation of rice planting or crop failure shock (Pandey et al. 2002), since growth and development, tillering and leaf growth are reduced (Dingkuhn et al. 1991.) This situation will worsen and undesirable impacts of dry seeding on yield improvement in rainfed areas will exacerbate as climate change progresses. Elsewhere, dry direct seeding was found to have higher yield compared with transplanted in a short-duration variety (Dingkuhn et al. 1991).

In the 1960s when irrigation capacity was still poor, the dry seeding technology was spontaneously spread in drought-prone lowlands in Japan and Korea. At that time, the manual drilling of rice seeds into the soil did not reduce the requirement for labor compared with that for transplanting (Himeda et al. 1975). In the case of rainfed lowlands in the Mekong regions, as well as in eastern India, farmers chose dry seeding (as a risk-reducing option) over transplanting in drought-prone fields located in higher elevations (Pandey et al. 2002). In Indonesia, a volcanic island country like the Philippines, the dry seeding technology called 'Gogorancah' was introduced to the drought-prone lowlands in central Java and the eastern islands in 1970s (Pandey et al. 2002). The technology enabled farmers to grow rice twice during the wet season and boosted annual crop production in rainfed areas.

While it potentially enables labor savings, all the experiences in other countries demonstrate that dry seeding of rice is, first and foremost, a yield-improving technology in drought-prone rainfed lowlands. In the Philippines, past trials on dry seeding in Pangasinan also indicated that this technology can stabilize and improve rice yield in rainfed lowlands (Pandey et al. 2002). Integrated weed management, which has been the main problem in direct seeding, has been much improved recently with the availability of pre-/post-emergence herbicides for rice farming (Chauhan 2012).

Another advantage of practicing dry direct seeding is the better performance of the non-rice upland crops that will be planted after rice. This is because in dry direct seeding, soil is not puddled, which spares soil physical properties from harm that even affects the crop after rice.

Multi-purpose Seeder: An innovation to traditional dry seeding

Poor crop establishment has been the most common yield constraint in the primitive method of dry seeding (i.e., broadcasting of seeds on the soil surface) (Pandey et al. 2002), as it makes the seeds vulnerable to serious bird and rat damages. Together with weed infestation, poor crop establishment is the main reason for the low adoption rate of the dry seeding technology. Farmers who practice dry seeding sow rice seeds at a very high rate, making this technology less cost-effective. However, even with a high seeding rate, the problem of poor crop establishment is inevitable in unreliable rainfall patterns. Broadcasted seeds cannot capture rainwater effectively and have to wait for ample rainfall to germinate and to develop root system. Mechanical row or line seeding like what the MP Seeder does, in contrast, enables rice seeds to be planted at the proper soil depth and distributed uniformly, resulting in uniform and stable crop stand (Pandey et al. 2002). Covering the seeds with soil ensures that germinated seeds can quickly utilize the available soil moisture. The seed's adhesion to soil facilitates root proliferation and faster water uptake under dry conditions (Kato and Katsura 2014). In addition, row seeding enables more efficient weed management than broadcasting (Chauhan 2012).

Previous studies reported several constraints in the use of mechanical seeders, all of which should be addressed step by step (Pandey et al. 2002). Limited seed flow due to seed clogging, limited residue-handling capability, and limited workability range in soil moisture are frequently encountered problems. Moreover, each of the currently used types of mechanical seeders, such as tine-type opener, disc-type opener, rotovator, and disc seeder, has its own strong and weak points.

The most important constraint for small farmers in using mechanical seeders is their high acquisition cost. Since mechanical seeding is a risk-reducing technology for rainfed lowland rice, technology adoption may depend upon the extent to which farmers are willing to pay for an expensive "insurance" against yield loss due to drought. This project thus seeks to promote multi-purpose seeders that may be used for high-value crops in addition to rice, in the hope that farmers would find the high acquisition cost to be mitigated by the additional income that can be earned from crop diversification. Designing machinery for multiple purposes reduces the operating costs per unit of machine. Manufacturing the machinery locally is another acquisition cost-reducing strategy while enhancing the capability of local communities to provide maintenance and service (Pandey et al. 2002).

The identification of rice varieties adapted to dry seeding is as important as the development of a hand tractor-mounted seeder. Upland rice varieties can generally tolerate dry and aerobic soils and show vigorous seedling growth. But their yield potential is low and they are not well-adapted to flooded conditions (Kato et al. 2009). Suitable varieties for mechanized dry seeding in rainfed lowland should have the following traits: (1) vigorous germination under limited soil moisture, (2) quick root anchorage onto the unsaturated hard soil, (3) vigorous seedling growth under aerobic conditions, (4) adaptation to flooded conditions with high yield potential, and (5) lodging resistance (Pandey et al. 2002). There are 25 Sahod-Ulan varieties now available here in the Philippines for rainfed areas, but it is crucial that the variety to be paired with the MP Seeder be adapted to the rice environment existing in an area. In addition, appropriate land preparation, seeding, and nutrient management techniques should also be identified to maximize productivity. Tillage intensity and depth affect the proportion of cloddy soils and the soil hardness at the surface layer, both of which are the critical factors affecting rice establishment in direct seeding (Kato and Katsura 2014). The appropriate timing and amount of basal fertilizer application to maximize fertilizer-use efficiency is also an important research issue.

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MP-FV
MP Seeder & Farmer's Variety
RENATO BELEN
PHOTO BY REMD

2

TECHNOLOGY GENERATION: Development of integrated best-management practices (BMP) for mechanized dry direct seeding for rice, corn, and mungbean using MP Seeder

Crisanta S. Bueno • Niño Paul Meynard C. Banayo • Roel R. Suralta • Emily E. Basuel • Liezel C. Peralta • Ruth A. Agbisit • Rene B. Carandang • Majho V. Pamplona • John Kenneth L. Motilla • Pompe C. Sta. Cruz

This chapter, which banners the first milestone of the project, comprises the first agronomy component. Three major activities were conducted under this milestone: (1) identify management options for improving crop establishment under dry direct seeding; (2) identify best nutrient and weed management packages for mechanized dry direct seeding for rice, corn, and mungbean; and (3) summarize existing developed technologies for corn and mungbean.

Three independent experiments were done to tackle the three tasks using varieties listed in Table 1: seeding depth, seeding rate, and nutrient management. Below, we discuss the methods and results of these experiments.

Seeding depth experiments in 11 sites covering 7 target regions determined the optimum depth that will lead to uniform seedling emergence under dry direct seeding (DDS) using MP Seeder (Table 1). These were laid out in RCBD with 4 replications, and 2-cm and 5-cm seeding depths as treatments. Seedling emergence rates were collected at 14 days after seeding (DAS) counted from 3 random positions within 1 linear meter sampling length. Plant biomass and tiller number were collected at 14, 30 (tillering stage), 50DAS (panicle initiation), and at flowering and physiological maturity. At maturity stage, yield and yield components (tiller and panicle counts, total grain weight, total unfilled spikelet weight, 1000-grain weight, 1000 unfilled spikelet weight and moisture content of filled grains) were measured.

Seeding rate experiments in 11 sites covering 7 target regions determined the best rate that produces good crop stand, higher yield and net income under DDS using MP Seeder (Table 1). These were laid out in RCBD with 4 replications, and seeding rates were 40, 60 and 120 $kg ha^{-1}$. Seedling emergence was measured at 14 DAS counted from 3 random positions within 0.5 linear meter per position.

Plant dry mass and tiller number were collected at 14, 30, 50 DAS, and at flowering and physiological maturity. At maturity stage, yield components and grain yield were determined.

Thorough land preparation, and optimum weed management (pre-and post herbicide as required) were done in all the setups. Basal fertilizer was applied on a per hectare basis at 40-40-40 N, P_2O_5, K_2O one day after emergence, then 40 N at 30 DAS and 20 N at panicle initiation.

Nutrient experiments in 11 sites covering 7 target regions were conducted to determine the optimum timing, rate, and fertilizer type that will give a good crop stand, higher yield and net income under DDS using MP Seeder (Table 1). These were laid out in RCBD with 4 replications. Treatments were: (T6) no basal application, 55 kg N applied at 30 DAS using complete fertilizer and 45 kg N applied at PI using urea; (T7) 40 kg N at basal, 30 kg N at 30 DAS, and 30 kg N at panicle initiation (PI) using ammonium sulphate; (T8) 40 kg N at basal, 30 kg N at 30 DAS, and 30 kg N at PI using urea; and (T9) 45 kg N at basal using complete fertilizer, 30 kg N at 30 DAS and at PI using Urea.

Agronomic data (plant height, tiller counts, plant biomass) were collected at 14, 30, and 50 DAS, at flowering and physiological maturity from a 1-linear-meter sampling length. At maturity stage, yield and yield components were determined.

Thorough land preparation and optimum weed management (pre-and post-herbicide as required) were implemented. Supplemental flush irrigation was applied during fertilizer application whenever necessary.

Table 1. On -farm researches for seeding depth, seeding rate, and nutrient trials for 2019 wet season.

Region	Province	Legend	Soil Texture	Ecosystem	Variety	Number/s
1	Ilocos Norte (Nueva Era)	NE	Sandy Loam	Drought-Prone (DP)	NSIC Rc 420	1
1	Pangasinan (Tayug)	PG1	Silt Loam	Drought-Prone (DP)	NSIC Rc 420	1
1	Pangasinan (Tayug)	PG2	Silt Loam	Favorable Rainfed (FR)	NSIC Rc 420	1
CAR	Abra (Pidigan)	CAR	Silty Clay	Drought-Prone (DP)	NSIC Rc 346	1
2	Cagayan (Lal-lo)	CV	Clay Loam	Drought-Prone (DP)	NSIC Rc 416	1
3	Tarlac (Paniqui)	TL	Silt Loam	Drought-Prone (DP)	NSIC Rc 420	1
5	Albay (Polangui)	AB	Clay	Favorable Rainfed (FR)	NSIC Rc 416	1
5	Camarines Sur (Calabanga)	CS	Clay	Tail End (TE)	NSIC Rc 416	1
6	Iloilo (Cabatuan)	IL	Clay	Drought-Prone (DP)	NSIC Rc 420	1
12	South Cotabato (Tantangan)	SC1	Loam	Drought-Prone (DP)	NSIC Rc 420	1
12	South Cotabato (Banga)	SC2	Sandy loam	Drought-Prone (DP)	NSIC Rc 420	1
Total						**11**

Seeding Depth

The experimental setup on seeding rate (SR) is shown in Figure 1. Seeding depth (2-cm [shallow] vs 5-cm [deep]) did not significantly affect seedling emergence in all sites, although 2-cm depth produced 32% more seedlings in Tarlac (Figure 1). At tillering stage (30 DAS), tillers were significantly higher (69%) in 2-cm depth than in 5-cm SD in Tarlac, becoming similar in the later growth stages. In Ilocos Norte, tillering at 30 DAS and panicle initiation was higher by 20% and 37% in 2-cm seeding depth, respectively. The same was observed in Camarines Sur where the 2-cm depth had 50% and 15% more tillers during the same stages but the differences later became negligible (Figure 2).

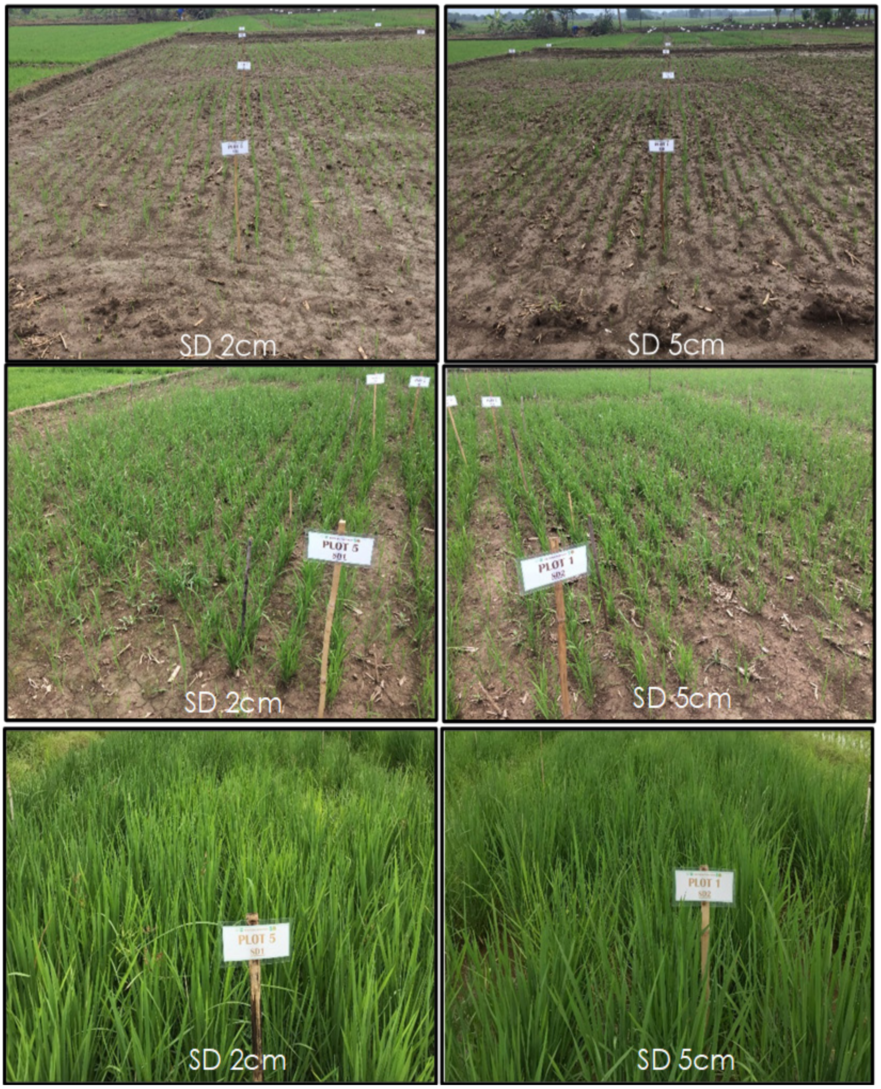

Figure 1. Sample pictures of 2-cm and 5-cm seeding depths (SD) (left to right) at 14, 30, and 50 DAS (top to bottom). Tarlac, 2019 WS.

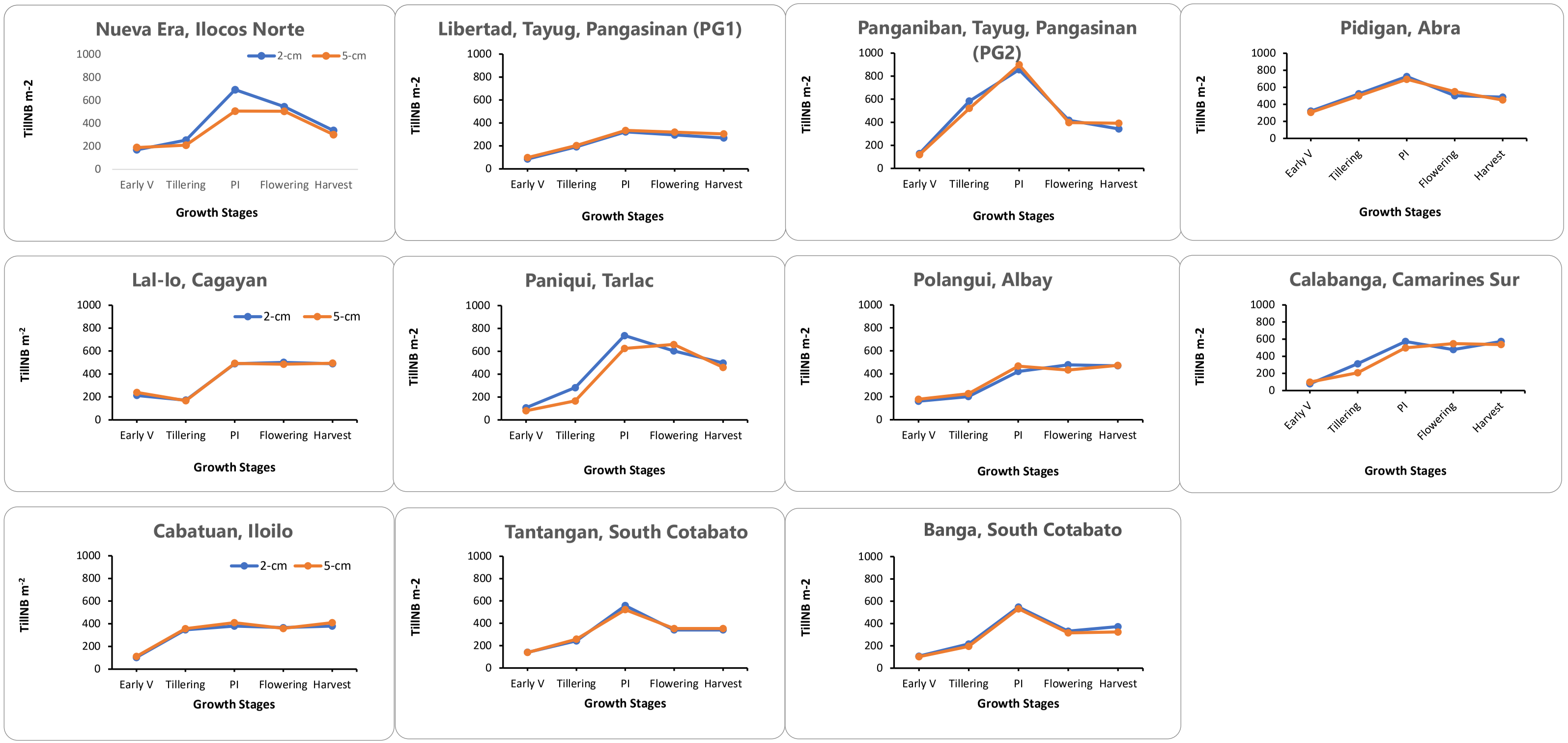

Figure 2. Tiller counts from early vegetative stage to harvest in seeding depth experiment, 2019 WS.

In terms of shoot dry mass, the 2-cm SD had higher values than the 5-cm SD depth at vegetative stage (14 and 30 DAS) in Tarlac, but became similar at panicle initiation (50 DAS) and maturity stages. Shoot dry mass in 2-cm SD was also higher at flowering in Iloilo, and at harvest in Ilocos Norte and Cagayan (Table 2). The rest of the experimental sites showed no significant differences in shoot dry mass between seeding depths.

Table 2. Shoot dry mass from early vegetative stage to harvest in seeding depth experiment, 2019 WS.

Site	Shoot dry mass (g m^2)									
	Early Vegetative (14 DAS)[a]		30DAS Tillering (30 DAS)		Panicle Initiation (50 DAS)		Flowering		Harvest	
	2-cm	5-cm	2-cm	5-cm	2-cm	5-cm	2-cm	5-cm	2-cm	5-cm
NE	3.66	3.26 *ns*	13.38	14 *ns*	195.05	134.41 *ns*	502.96	472.15 *ns*	1423.76	887.62 *ns*
PG1	2.58	4.61 *ns*	28.58	19.68 *ns*	96.18	80.79 *ns*	738	772.5 *ns*	729.1	861.5 *ns*
PG2	2.29	2.76 *ns*	80.63	78.35 *ns*	212	182.41 *ns*	954.17	769.2 *ns*	662.5	793 *ns*
CV	0.92	1.09 *ns*	50.98	45.79 *ns*	195.19	189.56 *ns*	771.5	771.25 *ns*	591.06	517.46 *
TL	5.30 a	1.90 *	36.00	14.00 *	251.71	254.75 *ns*	928.5	1115.25 *ns*	1465.25	1407.25 *ns*
CAR	5.16	5.62 *ns*	no data	no data	87.35	69.26 *ns*	495.06	594.49 *ns*	480.15	460.01 *ns*
AB	1.2	1.28 *ns*	10.8	10.73 *ns*	98.88	148.13 *ns*	682.45	650.42 *ns*	819.76	734.55 *ns*
CS	2.95	2.63 *ns*	8.4	8.46 *ns*	183.63	130.5 *ns*	666.62	691.42 *ns*	784.33	840.33 *ns*
IL	7.54	8.09 *ns*	58.3	44.7 *ns*	272.5	258.8 *ns*	610.1	437.27 *	646.25	627.25 *ns*
SC1 5.64		5.74 *ns*	23.8	24.8 *ns*	188.1	197.4 *ns*	674	742 *ns*	970	883.63 *ns*
SC2	6.08	4.1 *ns*	26.63	22.18 *ns*	149.7	160.51 *ns*	489	535 *ns*	954.38	843.75 *ns*

*[a]In a row within stages per site, mean followed by * is significant while ns is not significantly different at P 0.05 between seeding depths.*

In terms of grain yield, no significant differences between the two seeding depths were observed in all sites (Table 3) indicating that both can be used in dry direct seeding using MP Seeder (MPS). Thus, 2-cm SD was used in setting up other experiments.

Table 3. Grain yields obtained from seeding depth experiment, 2019 WS.

Site	GY, tons ha^{-1}	
	2-cm	**5-cm**
NE	2.43	2
PG1	3.76	3.83
PG2	3.7	3.78
CV	3.56	3.71
TL	2.82	3.38
CAR	2.08	1.86
AB	5.61	4.8
CS	4.6	3.95
IL	4.64	5.2
SC1	0.4	0.87
SC2	1.55	1.12

In a row within site, treatment means were not significantly different at P 0.05.

Seeding rate experiment

Seedling emergence was significantly higher with 120-kg/ha seeding rate compared with the 2 other seeding rates in 7 of the 11 experimental sites (Figure 3). Iloilo and South Cotabato did not significantly differ in seedling emergence among seeding rates. Emergence also did not significantly differ between the two lower rates (40 and 60 kg ha^{-1}) in most of the sites.

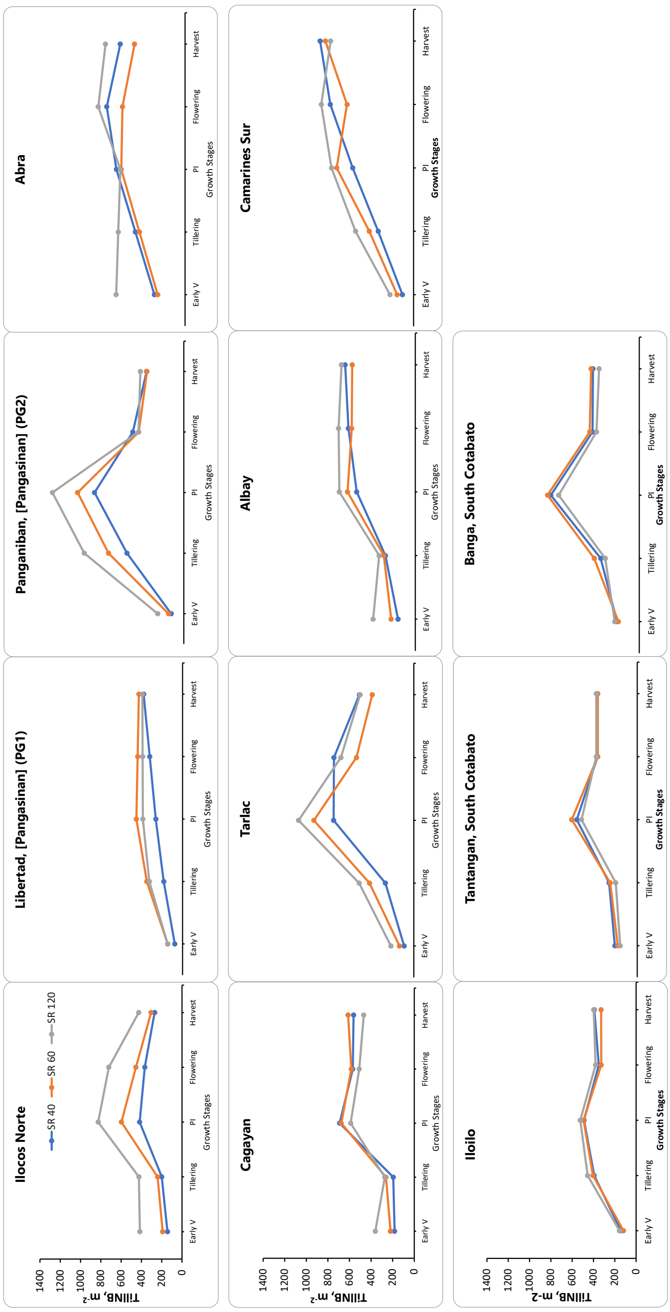

Figure 3. Tiller counts from early vegetative stage to harvest in seeding rate (SR) experiment, 2019 WS.
*Number of tillers at 14 DAS is the same as emergence count

The higher seedling emergence under 120-kg SR resulted in more tillers at tillering (30 DAS) and at panicle initiation (50 DAS) in 7 sites (Ilocos Norte, Pangasinan, Cagayan, Tarlac, Albay, Camarines Sur, and Iloilo). In general, the number of tillers under 40 kg ha^{-1} SR compared with 60 and 120 kg ha^{-1} was significantly lower only during the vegetative stage. Tiller production was similar under all rates in Iloilo and South Cotabato (Figure 3).

The effect of seeding rate was notable in 30 DAS (vegetative stage) in Ilocos Norte and Pangasinan where the 120 kg/ha rate showed a significantly higher shoot dry mass than either 60 or 40 kg ha^{-1}. However, these differences were no longer observed in the later stages of growth. For the rest of the sites, shoot dry mass did not significantly differ (Table 4).

Table 4. Shoot dry mass at different growth stages as affected by seeding rates and locations, 2019 WS.

Site	Shoot dry mass (g m^2)														
	Early Vegetative (14 DAS)			30DAS Tillering (30 DAS)			Panicle Initiation (50 DAS)			Flowering			Harvest		
	SR40	SR60	SR120	SR40	SR60	SR120	SR40	SR60	SR120	SR40	SR60	SR120	SR40	SR60	SR120
NE	-	-	-	16.00 b	19.25 b	29.25 a	143.97 a	130.05 a	168.13 a	304.67 a	306.97 a	438.75 a	778.67a	936.75 a	1423.00 a
PG1	4.38 a	4.03 a	5.70 a	22.00 b	18.00 b	55.00 a	78.35 a	72.33 a	120.58 a	1136.75 a	827 a	898.25 a	872.88 a	1009.50 a	803.00 a
PG2	4.38 a	4.03 a	5.70 a	73.33 a	92.15 a	90.80 a	277.55 a	275.35 a	361.40 a	880.92 b	1281.92 a	1011.83 ab	817.69 a	804.05 a	801.175 a
CV	-	-	-	10.40 a	23.57 a	10.53 a	149.58 a	240.95 a	149.33 a	627.42 a	802.40 a	846.65 a	1406.00 a	1164.80 a	1021.02 a
TL	-	-	-	26.95 a	49.20 a	57.53 a	311.00 a	273.35 a	331.63 a	1326.25 a	1168.00 a	1092.50 a	1353.13 a	930.88 a	962.25 a
CAR	-	-	-	-	-	-	115.05 a	114.52 a	98.57 a	762.77 a	620.88 a	656.67 a	1135.90 a	969.67 a	1036.97 a
AB	-	-	-	11.80 a	13.10 a	16.70 a	118.30 b	227.00 a	241.80 a	754.73 a	801.20 a	916.55 a	918.35 a	947.02 a	805.67 a
CS	-	-	-	18.80 a	19.60 a	24.00 a	158.30 a	208.50 a	246.80 a	791.12 a	612.97 ab	504.88 b	790.07 a	674.37 a	813.91 a
IL	-	-	-	60.90 a	52.50 a	61.20 a	264.70 a	278.00 a	259.50 a	502.75 a	640.52 a	615.57 a	712.88 a	634.12 a	707.62 a
SC1	-	-	-	22.50 a	28.90 a	21.00 a	159.50 a	308.20 a	158.50 a	878.50 a	795.20 a	716.40 a	872.50 a	802.50 a	878.12 a
SC2	-	-	-	44.50 a	75.50 a	40.70 a	297.30 a	244.30 a	195.20 a	789.00 a	1147.00 a	632.00 a	858.88 a	974.37 a	643.75 a

In a row within growth stages, means followed by the same letter are significantly different at P0.05.

No significant effects of seeding rates (40,60,120 kg ha^{-1}) were observed among regions on grain yield, although it varied among sites: highest in Albay, followed by Tarlac, Camarines Sur, and Pangasinan. Low grain yields were observed in South Cotabato and Ilocos Norte (Table 5).

Table 5. Grain yields obtained from seeding rate (SR) experiment, 2019 WS.

Site	GY, tons ha^{-1}		
	SR40	**SR60**	**SR120**
NE	1.63	1.34	1.86
PG1	3.87	3.52	3.25
PG2	3.25	3.13	2.81
CV	3.83	3.63	3.44
TL	4.16	4.16	3.76
CAR	1.96	1.85	2.18
AB	4.85	4.20	4.95
CS	3.40	3.70	3.10
IL	4.61	4.01	4.86
SC1	1.34	0.62	1.51
SC2	1.57	1.55	0.83

In a row within site, no significant difference was observed at P0.05 among SR treatments.

Figure 4. On-site experimental field for seeding depth and rate, and nutrient management trials, Pangasinan, 2019 WS.

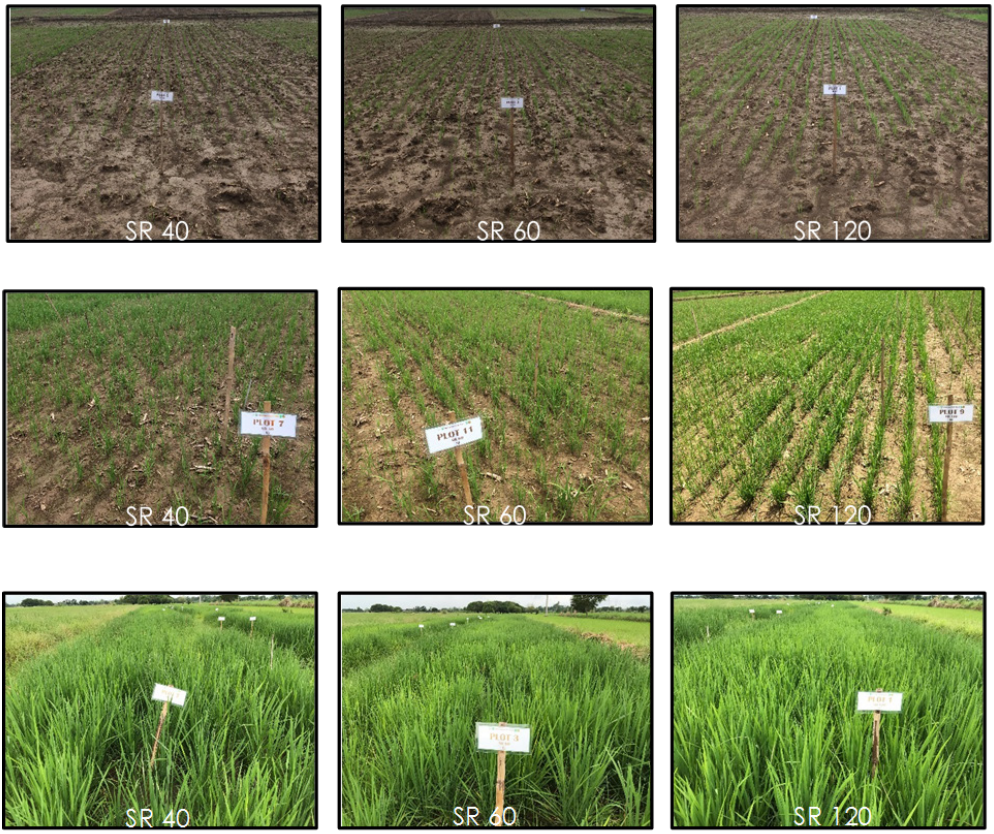

Figure 5. Sample pictures of the seeding rate experiment (left to right) at 14, 30, and 50 DAS (top, middle, and bottom), Pangasinan, 2019 WS.

Additional seeding rate experiments in 2020 WS

Trials were established in 2020 WS from June to July in Ilocos Norte (Nueva Era and Batac City) and Tarlac (Victoria) to confirm results from the 2019 WS. The MP Seeder was set at 2-cm seeding depth for ease of operation, since previous data indicated no yield advantage under 5-cm seeding depth.

Significantly more seedlings emerged with SR120 at 14 DAS in all three research sites (Table 6). SR40 had lower seedling emergence than SR60 in Nueva Era but SR40 and SR60 significantly differed in the Batac and Victoria trials. The higher tiller number was sustained in SR120 until harvest in Victoria, but until flowering stage only in Nueva Era.

Table 6. Tiller numbers at different growth stages as affected by seeding rates (SR) and locations, 2020 WS.

Stages	Treatment	Tiller number		
		Nueva Era, Ilocos Norte (DP)	Batac City, Ilocos Norte (DP)	Victoria, Tarlac
	SR40	53 b	62 b	56 b
Early Vegetative (14 DAS) *	SR60	111 a	67 b	84 b
	SR120	143 a	100 a	165 a
	SR40	122 b	62 b	152 b
Tillering (30 DAS)	SR60	201 a	67 b	183 ab
	SR120	254 a	100 a	230 a
	SR40	103 b	62 a	182 c
Panicle Initiation (50 DAS)	SR60	165 a	55 a	206 b
	SR120	179 a	85 a	245 a
	SR40	98 b	41 b	122 b
Flowering	SR60	118 ab	45 b	126 b
	SR120	134 a	67 a	176 a
	SR40	109 a	-	154 b
Harvest	SR60	122 a	-	161 b
	SR120	131 a	-	207 a

In a column within each stage per site, SR means followed by the same letter are significantly different at P0.05.

Effects of seeding rates on shoot dry mass were significantly different at early vegetative and tillering stages. SR40 had lower shoot dry mass than SR60 and SR120, but these differences disappeared at flowering and at harvest (Table 7). SR40 and SR60 treatments performed like SR120 efficiently utilizing the greater spaces and soil resources.

Table 7. Shoot dry mass at different growth stages as affected by seeding rates (SR) and locations, 2020 WS.

Stages	Treatment	Shoot biomass, g m^{-2}		
		Nueva Era, Ilocos Norte (DP)	Batac City, Ilocos Norte (DP)	Victoria, Tarlac
Early Vegetative (14 DAS)*	SR40	0.18 b	0.18 b	4.28 b
	SR60	0.55 a	0.55 a	8.00 b
	SR120	0.65 a	0.65 a	13.38 a
Tillering (30 DAS)	SR40	37.75 b	24.50 b	112.75 b
	SR60	50.25 b	40.75 a	174.00 a
	SR120	90.50 a	49.25 a	204.50 a
Panicle Initiation (50 DAS)	SR40	370.75 a	226.50 b	494.85 a
	SR60	393.75 a	310.00 a	640.85 a
	SR120	424.75 a	307.50 a	633.77 a
Flowering	SR40	1198.75 a	661.00 a	713.25 a
	SR60	1330.00 a	703.25 a	753.25 a
	SR120	1254.00 a	721.25 a	903.50 a
Harvest	SR40	852.42 a	-	2806.75 a
	SR60	882.25 a	-	2665.50 a
	SR120	813.42 a	-	3074.50 a

In a column within each stage per site, SR means followed by the same letter are significantly different at P0.05.

Grain yields were not significantly different among seeding rates (Table 8), but Tarlac yielded higher than Ilocos Norte. No data was collected at harvest in Batac due to typhoon damage.

Table 8. Grain yields at different growth stages as affected by seeding rates (SR). 2020 WS.

Treatment	GY, t ha^{-1}	
	Nueva Era, Ilocos Norte (DP)	Victoria, Tarlac
SR40	2.06 a	4.01 a
SR60	2.83 a	4.01 a
SR120	2.68 a	4.22 a

**In a column within site, means followed by the same letter are significantly different at P0.05.*

Nutrient Management

Number of tillers was not significantly different among nutrient management treatments in all growth stages and in most sites except in Tarlac under drought-prone conditions at tillering stage (30 DAS) (Table 9).

Table 9. Tiller numbers from early vegetative stage to flowering/harvest on nutrient management experiment, 2019 WS.

Site	Number of Tillers per m²																			
	Early Vegetative (14 DAS)				Vegetative (30 DAS)				Panicle Initiation (50 DAS)				Flowering				Harvest			
	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)
Timing	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45
NE	235 a	201 a	181 a	178 a	no data	no data	no data	no data	253 a	310 a	355 a	256 a	614 a	663 a	551 a	466 a	455 a	416 a	413 a	481 a
PG1	95 a	104 a	95 a	105 a	295 a	496 a	433 a	391 a	458 a	416 a	483 a	593 a	356 a	289 a	349 a	304 a	399 a	376 a	388 a	350 a
PG2	115 a	101 a	93 a	103 a	425 a	438 a	470 a	526 a	746 a	895 a	795 a	731 a	443 a	409 a	409 a	371 a	445 a	435 a	389 a	414 a
CV	150 a	164 a	165 a	174 a	106 a	168 a	124 a	119 a	399 a	369 a	293 a	298 a	501 a	541 a	540 a	544 a	583 a	569 a	541 a	464 a
TL	153 a	170 a	165 a	218 a	176 c	260 b	334 a	304 ab	635 a	576 a	658 a	576 a	481 a	510 a	475 a	443 a	419 a	393 a	408 a	378 a
CAR	266 a	244 a	259 a	209 a	no data	no data	no data	no data	359 a	314 a	351 a	321 a	827 a	760 a	755 a	735 a	593 a	659 a	689 a	596 a
AB	200 a	133 a	153 a	170 a	249 a	291 a	280 a	268 a	418 a	398 a	495 a	486 a	508 a	445 a	500 a	419 a	538 a	676 a	621 a	578 a
CS	79 a	75 a	89 a	80 a	253 a	223 a	266 a	243 a	451 a	625 a	469 a	650 a	444 a	541 a	439 a	500 a	628 a	678 a	689 a	678 a
IL	109 a	138 a	123 a	134 a	353 a	380 a	218 a	365 a	573 a	539 a	504 a	506 a	300 a	279 a	281 a	363 a	449 a	390 a	365 a	386 a
SC1	151 a	174 a	174 a	148 a	286 a	368 a	388 a	280 a	674 a	519 a	499 a	459 a	-	-	-	-	479 a	434 a	489 a	479 a
SC2	131 a	156 a	164 a	153 a	321 a	340 a	383 a	403 a	1018 a	748 a	990 a	753 a	-	-	-	-	532 a	443 b	434 b	528 a

In a row within each stage per site, treatment means followed by the same letter are not significantly different at P 0.05.

Shoot dry mass did not significantly differ among nutritional management treatments at advanced growth stages in most sites except in South Cotabato during flowering stage (Table 10). Those applied with complete fertilizer and urea had significantly higher shoot dry mass with 811 g m^2 compared with other treatments (501-627 g m^2).

Table 10. Shoot dry mass at various growth stages as affected by different nutrient management experiments and locations, 2019 WS.

Site	Shoot dry mass (g m^2)																			
	Early Vegetative (14 DAS)				30 DAS Tillering (30 DAS)				Panicle Initiation (50 DAS)				Flowering				Harvest			
	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)
Timing	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45
NE	6.96 a	8.15 a	8.53 a	6.89 a	no data	no data	no data	no data	77.56 a	111.50 a	146.76 a	73.46 a	393.68 a	549.29 a	500.16 a	388.25 a	533.62 a	765.88 a	748.75 a	766.38 a
PG1	2.15 a	2.56 a	2.31 a	3.04 a	45.00 a	97.00 a	84.00 a	89.00 a	134.05 a	132.39 a	156.65 a	202.96 a	757.50 a	668.88 a	774.00 a	713.75 a	1076.00 a	952.50 a	885.00 a	1050.00 a
PG2	2.66 a	2.76 a	2.63 a	2.89 a	56.45 a	68.31 a	74.94 a	89.45 a	218.75 a	277.08 a	262.91 a	228.45 a	1015.55 a	946.33 a	952.58 a	886.65 a	993.7 a	879.2 a	902.5 a	957.4 a
CV	1.85 a	1.62 a	1.54 a	1.63 a	8.15 a	17.54 a	9.90 a	10.14 a	85.76 a	100.75 a	86.4 a	69.29 a	613.84 a	622.51 a	593.83 a	555.53 a	619.04 a	576.88 a	530.21 a	444.40 a
TL	3.21 a	4.15 a	4.11 a	5.55 a	19.00 b	36.00 a	41.00 a	40.00 a	328.58 a	282.54 a	345.08 a	308.23 a	869.87 a	891.00 a	913.50 a	851.00 a	1058.30 a	968.40 a	928.30 a	992.40 a
CAR	4.37 a	4.73 a	5.66 a	3.32 a	no data	no data	no data	no data	26.28 a	33.58 a	34.15 a	36.96 a	554 a	559 a	649 a	638 a	526.27 a	515.36 a	628.29 a	533.84 a
AB	1.51 a	1.36 a	1.3 a	1.59 a	10.40 a	15.60 a	13.80 a	15.60 a	112.40 a	111.40 a	145.10 a	114.30 a	766.70 a	583.00 a	774.20 a	619.60 a	874.35 a	978.16 a	947.09 a	943.69 a
CS	2.66 a	3.40 a	4.19 a	3.89 a	9.50 a	13.40 a	15.00 a	14.50 a	122.40 a	222.60 a	158.90 a	229.60 a	474.60 a	615.10 a	507.00 a	624.20 a	799.79 a	884.65 a	836.91 a	884.05 a
IL	8.35 a	11.46 a	11.16 a	12.61 a	55.90 ab	71.30 a	34.90 b	73.60 a	250.50 a	309.70 a	257.10 a	330.80 a	535.80 a	438.40 a	560.70 a	624.40 a	1037.12 a	996.62 a	817.38 a	945.5 a
SC1	6.36 a	7.10 a	8.08 a	5.60 a	29.23 a	36.85 a	36.15 a	30.96 a	254.14 a	194.46 a	173.91 a	150.78 a	810.88 a	672.47 ab	524.67 b	500.96 b	999.38 a	821.25 a	889.38 a	840.80 a
SC2	10.51 a	11.31 a	14.66 a	9.1 a	49.08 a	47.60 a	55.31 a	63.38 a	313.90 ab	228.10 b	409.20 a	224.80 b	933.62 a	772.08 a	793.96 a	916.88 a	1081.88 a	672.50 b	834.38 ab	1116.88 a

In a row within each stage per site, treatment means followed by the same letter are not significantly different at P0.05.

Table 11. Plant height from early vegetative stage to flowering/harvest on nutrient management experiments, 2019 WS.

Site	Plant Height, cm																			
	Early Vegetative (14 DAS)				30 DAS Tillering (30 DAS)				Panicle Initiation (50 DAS)				Flowering				Harvest			
	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)	Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)
Timing	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45	30, 45	0, 30, 45	0, 30, 45	0, 30, 45
NE	17.17 a	18.85 a	18.72 a	17.05 a	no data	no data	no data	no data	46.34 a	49.82 a	53.58 a	43.99 a	49.05 a	60.09 a	60.9 a	58.8 a	76.72 c	89.19 a	85.54 ab	82.74 b
PG1	45.05 a	44.16 a	42.84 a	46.09 a	38.00 c	43.00 ab	40.00 bc	44.00 a	45.05 a	44.16 a	42.84 a	46.09 a	100.62 a	101.62 a	105.40 a	105.10 a	123.48 a	100.92 a	97.15 a	103.62 a
PG2	14.29 a	14.66 a	15.05 a	15.48 a	34.13 a	35.19 a	35.98 a	36.39 a	59.15 a	58.22 a	61.21 a	60.20 a	108.06 a	106.71 a	107.83 a	109.37 a	123.48 a	121.41 a	120.51 a	120.74
CV	6.85 a	8.03 a	7.60 a	7.15 a	22.01 a	23.94 a	22.12 a	24.64 a	43.62 a	46.46 a	41.82 a	40.85 a	49.05 a	60.09 a	60.90 a	58.80 a	94.60 a	93.80 a	91.74 a	89.91 a
TL	22.48 a	18.73 a	17.93 a	19.36 a	38.00 b	43.00 a	44.00 a	42.00 a	66.57 a	63.90 a	66.99 a	66.24 a	113.38 a	112.55 a	110.00 a	113.93 a	117.10 a	114.67 a	116.12 a	117.1
CAR	14.05 a	14.60 a	15.27 a	16.67 a	no data	no data	no data	no data	57.35 a	49.45 b	57.23 a	54.73 a	68.00 a	78.36 a	75.30 a	74.08 a	88.10 a	86.29 a	107.53 a	86.16 a
AB	13.40 a	14.00 a	13.80 a	13.90 a	19.60 b	22.00 a	22.00 a	22.80 a	56.70 a	71.00 a	59.10 a	61.60 a	100.70 a	98.50 a	100.00 a	98.00 a	101.64 a	101.91 a	100.78 a	100.78 a
CS	15.70 b	18.00 a	18.30 a	18.90 a	23.80 a	22.90 a	21.80 a	22.50 a	52.60 a	56.30 a	56.60 a	57.30 a	94.60 a	94.00 a	94.60 a	97.80 a	94.64 a	954.83 a	96.47 a	97.52 a
IL	23.00 b	26.30 ab	27.70 a	29.40 a	38.30 b	45.90 a	47.20 a	45.00 a	62.40 b	76.90 a	57.20 b	75.60 a	116.30 a	114.50 a	120.00 a	118.50 a	102.85 a	103.15 a	102.15 a	106.42 a
SC1	22.60 a	22.60 a	24.70 a	22.50 a	38.80 a	124.90 a	38.70 a	37.40 a	63.50 a	55.40 a	56.90 a	52.40 a	93.59 a	85.39 a	87.99 a	81.34 a	99.35 a	92.49 a	95.06 a	90.59 a
SC2	23.10 a	22.80 a	24.20 a	22.20 a	39.50 a	38.60 a	39.20 a	38.90 a	70.10 a	57.00 b	62.20 b	62.10 b	101.20 a	91.20 a	98.80 a	95.89 a	107.74 a	102.71 a	104.83 a	106.20 a

In a row within each stage per site, treatment means followed by the same letter/s are not significantly different at P0.05.

In terms of grain yield, there were significant differences among treatments in Abra, Pangasinan, Camarines Sur, Albay, Iloilo and South Cotabato (Table 12). Fertilizer N application interacted with the existing soil type in a given site, such as clay in Albay, Camarines Sur, and Iloilo; silty clay in Abra; silty loam in Pangasinan; and sandy loam in South Cotabato. The results suggest that the different soil characteristics and climatic conditions affected fertilizer efficiency and in turn grain yield. Since yield differences were observed in these sites, the basal application of complete fertilizer is still recommended followed by split application of ammonium sulfate (depending on soil degradation i.e. sulfur deficiency/toxicity) or urea during vegetative and panicle initiation stages. Also, first fertilizer application can be done 0 to 30 DAS when field soil moisture becomes favorable.

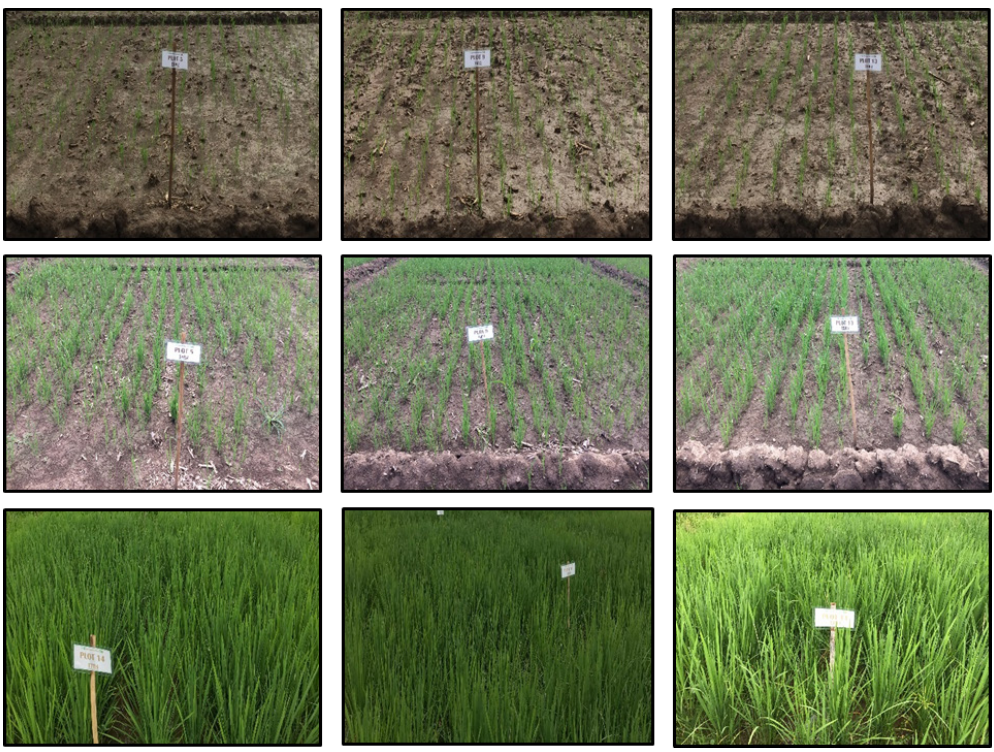

Figure 6. Sample photos of nutrient management at 14, 30, and 50 DAS (top, middle, and bottom).

Table 12. Grain yields (GY) as affected by different nutrient management and locations, 2019 WS.

Site	Soil Type	GY, tons ha-1			
		Complete + urea (T6)	Ammosul (T7)	Urea (T8)	Complete + urea (T9)
Timing (DAS)		30, 45	0, 30, 45	0, 30, 45	0, 30, 45
AB	Clay	4.78 b	5.01 ab	5.26 a	5.02 ab
CS		4.61a	3.89 c	4.10 bc	4.56 ab
IL		5.50 a	1.94 c	1.52 c	4.20 b
CG	Clay Loam	3.10 a	3.30 a	3.22 a	3.40 a
AR	Silt Clay	3.74 a	3.04 b	3.27 ab	3.25 ab
SC1	Loam	3.30 a	2.34 a	2.91a	2.33 a
PG1	Silt Loam	4.27 a	4.28 a	4.01 b	4.50 a
PG2		3.51 a	3.40 a	3.53 a	3.82 a
TL		4.12 a	4.12 a	4.21 a	3.99 a
IN	Sandy Loam	2.00 a	2.14 a	1.87 a	2.20 a
SC2		2.78 bc	2.70 c	3.13 b	3.70 a

In a row within each site, treatment means followed by the same letter/s are not significantly different at P0.05.

Confirmatory Fertilizer trials, 2020 WS

Three additional nutrient experimental trials were established in 2020 WS from June to July in Ilocos Norte (Nueva Era and Batac City) and Tarlac (Victoria) to confirm results from the 2019 WS setups.

Treatments used are presented in Table 13. The MP Seeder was set to 2-cm seeding depth in these trials.

Table 13. Treatments for nutrient management trials, 2020 WS.

Treatments	Sources	Timing	N			Applied as basal	
			Basal	AT	PI	P_{205}	K_{20}
			----	30 DAS	45 DAS		
6	Complete	30 DAS	0	55	45	40	40
7	Ammosul	0 DAS	40	30	30	40	40
8	Urea	0 DAS	40	30	30	40	40
9	Complete	0 DAS	40	30	30	40	40

Basal fertilizer application was done after crop establishment and supplemental flush irrigation was applied whenever necessary. Thorough land preparation and application of pre-emergence herbicide as required were implemented.

Nutrient management trials: fertilizer source and timing of application did not significantly affect the number of emerged seedlings at 14 DAS in Ilocos Norte (Table 14). The number of tillers counted at 30 and 50 DAS did not differ among treatments. However, at flowering, number of tillers under T6 treatment in Nueva Era was significantly higher compared with other treatments.

Table 14. Tiller numbers from early vegetative stage to flowering/harvest in nutrient management experiments 2020 WS.

Stages	Treatments	Timing (DAS)	Tiller number		
			Nueva Era, Ilocos Norte (DP)	Batac City, Ilocos Norte (DP)	Victoria, Tarlac
Early Vegetative (14 DAS)	(T6) Complete + urea	30, 45	188 a	128 a	206 a
	(T7) Ammosul	0, 30, 45	164 a	129 a	230 a
	(T8) Urea	0, 30, 45	169 a	139 a	189 a
	(T9) Complete + urea	0, 30, 45	175 a	100 a	219 a
Tillering (30 DAS)	(T6) Complete + urea	30, 45	183 a	135 a	204 a
	(T7) Ammosul	0, 30, 45	204 a	100 a	230 a
	(T8) Urea	0, 30, 45	194 a	115 a	194 a
	(T9) Complete + urea	0, 30, 45	259 a	111 a	188 a
Panicle Initiation (50 DAS)	(T6) Complete + urea	30, 45	340 a	350 a	269 a
	(T7) Ammosul	0, 30, 45	313 a	273 a	311 a
	(T8) Urea	0, 30, 45	383 a	283 a	280 a
	(T9) Complete + urea	0, 30, 45	303 a	283 a	378 a
Flowering	(T6) Complete + urea	30, 45	795 a	373 a	296 a
	(T7) Ammosul	0, 30, 45	583 b	273 a	323 a
	(T8) Urea	0, 30, 45	558 b	283 a	295 a
	(T9) Complete + urea	0, 30, 45	598 b	288 a	283 a
Harvest	(T6) Complete + urea	30, 45	900 a	-	591.25 a
	(T7) Ammosul	0, 30, 45	730 a	-	456.25 b
	(T8) Urea	0, 30, 45	695 a	-	470.00 b
	(T9) Complete + urea	0, 30, 45	698 a	-	491.25 b

In a column within each stage per site, treatment means followed by the same letter are not significantly different at P0.05.

Like the number of tillers, the shoot dry biomass was not statistically different at 14, 30, 50 DAS, flowering, and harvest (Table 15).

Table 15. Shoot dry mass at advancing growth stages as affected by different nutrient management experiments and locations, 2020 WS.

Stages	Treatments	Timing (DAS)	Shoot biomass, g m^{-2}		
			Nueva Era, Ilocos Norte (DP)	Batac City, Ilocos Norte (DP)	Victoria, Tarlac
Early Vegetative (14 DAS) *	(T6) Complete + urea	30, 45	0.28 a	0.20 a	1.21 a
	(T7) Ammosul	0, 30, 45	0.20 a	0.14 a	2.92 a
	(T8) Urea	0, 30, 45	0.18 a	0.16 a	1.66 a
	(T9) Complete + urea	0, 30, 45	0.20 a	0.15 a	2.71 a
Tillering (30 DAS)	(T6) Complete + urea	30, 45	14.13 a	12.12 a	10.32 a
	(T7) Ammosul	0, 30, 45	25.00 a	19.00 a	23.99 a
	(T8) Urea	0, 30, 45	17.00 a	16.00 a	11.96 a
	(T9) Complete + urea	0, 30, 45	19.38 a	15.75 a	16.40 a
Panicle Initiation (50 DAS)	(T6) Complete + urea	30, 45	210.00 a	180.00 a	41.08 a
	(T7) Ammosul	0, 30, 45	266.25 a	228.50 a	72.79 a
	(T8) Urea	0, 30, 45	235.50 a	203.25 a	46.36 a
	(T9) Complete + urea	0, 30, 45	240.25 a	190.50 a	78.51 a
Flowering	(T6) Complete + urea	30, 45	705.75 a	499.75 a	272.25 a
	(T7) Ammosul	0, 30, 45	897.75 a	517.25 a	375.38 a
	(T8) Urea	0, 30, 45	735.75 a	508.25 a	267.75 a
	(T9) Complete + urea	0, 30, 45	844.00 a	474.75 a	313.75 a
Harvest	(T6) Complete + urea	30, 45	2159.25 a	-	1141.00 a
	(T7) Ammosul	0, 30, 45	1639.75 a	-	927.75 a
	(T8) Urea	0, 30, 45	1665.00 a	-	898.88 a
	(T9) Complete + urea	0, 30, 45	1576.25 a	-	928.88 a

In a column within each stage per site, treatment means followed by the same letter are not significantly different at P0.05.

Plant height as affected by fertilizer treatments from early vegetative to harvest was not significantly different in both Ilocos Norte sites (Table 16).

Table 16. Plant height from early vegetative stage to flowering/harvest in nutrient management experiments 2020 WS.

Stages	Treatments	Timing (DAS)	Plant Height, cm		
			Nueva Era, Ilocos Norte (DP)	Batac City, Ilocos Norte (DP)	Victoria, Tarlac
Early Vegetative (14 DAS) *	(T6) Complete + urea	30, 45	9.60 a	8.62 a	8.18 a
	(T7) Ammosul	0, 30, 45	9.70 a	9.85 a	12.01 a
	(T8) Urea	0, 30, 45	9.70 a	9.48 a	9.63 a
	(T9) Complete + urea	0, 30, 45	10.19 a	9.44 a	10.12 a
Tillering (30 DAS)	(T6) Complete + urea	30, 45	23.98 a	25.52 a	18.22 a
	(T7) Ammosul	0, 30, 45	27.92 a	20.70 a	23.94 a
	(T8) Urea	0, 30, 45	27.34 a	27.17 a	18.67 a
	(T9) Complete + urea	0, 30, 45	29.23 a	26.88 a	21.76 a
Panicle Initiation (50 DAS)	(T6) Complete + urea	30, 45	50.03 a	46.45 a	31.53 b
	(T7) Ammosul	0, 30, 45	52.74 a	47.53 a	39.74 a
	(T8) Urea	0, 30, 45	48.73 a	45.65 a	32.94 b
	(T9) Complete + urea	0, 30, 45	52.98 a	46.54 a	40.06 a
Flowering	(T6) Complete + urea	30, 45	76.35 a	68.85 a	66.16 a
	(T7) Ammosul	0, 30, 45	79.99 a	68.10 a	73.92 a
	(T8) Urea	0, 30, 45	75.40 a	67.25 a	65.05 a
	(T9) Complete + urea	0, 30, 45	77.39 a	66.38 a	69.24 a
Harvest	(T6) Complete + urea	30, 45	71.31 a	-	80.14 a
	(T7) Ammosul	0, 30, 45	70.12 a	-	81.78 a
	(T8) Urea	0, 30, 45	70.04 a	-	78.44 a
	(T9) Complete + urea	0, 30, 45	68.67 a	-	79.50 a

In a column within each stage per site, treatment means followed by the same letter are not significantly different at P0.05.

Grain yield was not significantly affected by the different fertilizer treatments (Table 17). It ranged from 2.77 to 2.98 t ha^{-1} in Nueva Era; 2.57 to 3.44 t ha^{-1} in Tarlac. No data was collected in Batac City due to typhoon damage.

Table 17. Grain yields (GY) as affected by different nutrient management and locations, 2020 WS.

Treatments	Timing (DAS)	GY, tons ha^{-1}	
		Nueva Era, Ilocos Norte (DP)	Victoria, Tarlac
(T6) Complete + urea	30, 45	2.98 a	2.57 a
(T7) Ammosul	0, 30, 45	2.87 a	3. 44 a
(T8) Urea	0, 30, 45	2.77 a	2.50 a
(T9) Complete + urea	0, 30, 45	2.83 a	2.82 a

In a column within site, treatment means followed by the same letter are not significantly different at P0.05.

Additional nutrient trials in UPLB, Laguna 2020 WS

To evaluate the effects of fertilizer source and timing of application for the development of best management package for dry direct seeding, technology generation trials were conducted in UP Los Baños with silty clay loam soil using NSIC Rc420 variety. N sources and a control (0NPK) (Table 18) were imposed in a randomized complete block design with four replicates. For treatments 7 and 8, the sources of P and K were P_{2O5} and K_{20} respectively, applied at 0 DAS at a rate of 40 kg ha^{-1}. Bunds and canals within the plots were built to prevent seepage/overlapping of applied fertilizers.

At 14 DAS, a one-linear-meter area was randomly identified for counting of emergence and plant height measurement from 10 random plants, and all plants in the area were collected for aboveground biomass measurement. Except at 30 DAS, instead of one linear meter, a 0.5-linear-meter portion was identified per plot at 48 DAS (early PI), 61 DAS, and flowering for plant height measurement (using 10 random plants). All plants were collected for aboveground biomass, tiller count, and panicle count at flowering. At physiological maturity, grain yield was determined from a 5-m^2 area and samples for yield component determination were collected from 2 positions of 0.5 linear meter.

Table 18. Fertilizer type, rate, and timing of application, UPLB, 2020 WS.

Treatment #	N Source	Timing	N rate, kg ha^{-1}
T6	Complete	30 DAS	40
	Urea		15
		45 DAS	45
T7		0 DAS	40
	Ammonium sulfate	30 DAS	30
		45 DAS	30
T8		0 DAS	40
	Urea	30 DAS	30
		45 DAS	30
T9	Complete	0 DAS	40
	Urea	30 DAS	30
		45 DAS	30
T10	Control		0

Tiller number increased linearly during the vegetative phase and maximum tillering was attained at 48 DAS. Number decreased from panicle initiation (PI) until physiological maturity (PM). Tillers in the control were less than the other treatments (Figure 7).

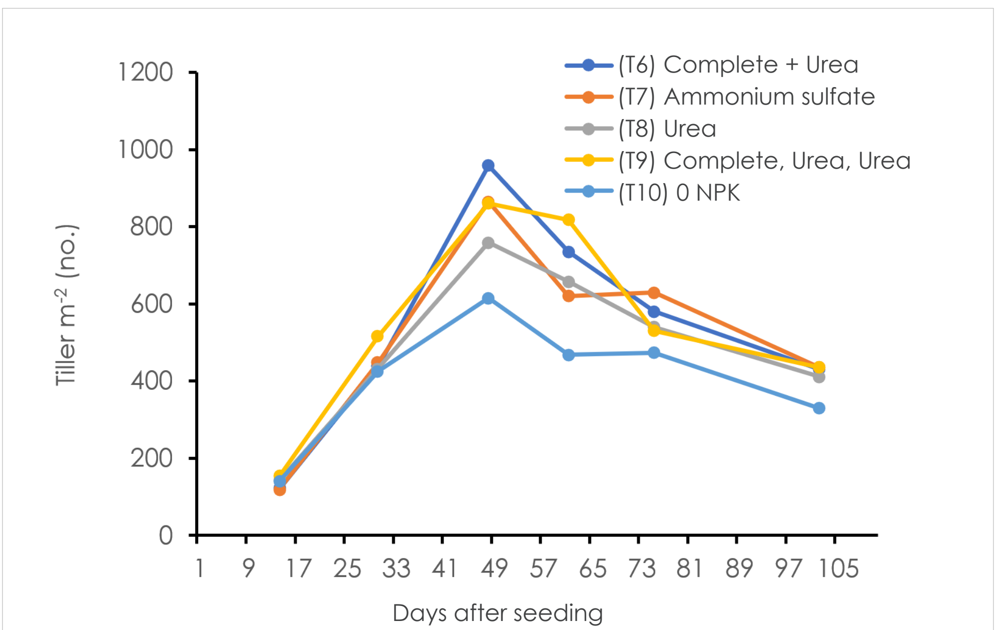

Figure 7. Number of tillers per m^2 at different growth stages, UPLB, 2020 WS.

Shoot dry mass increased from tillering until physiological maturity except for the control (no fertilizer added) (Figure 8).

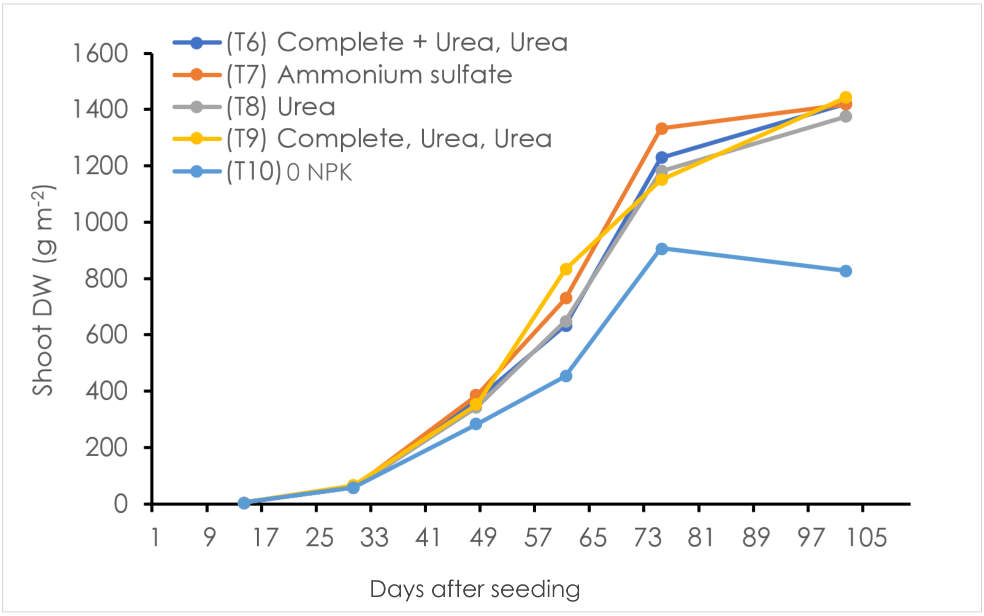

Figure 8. Dynamics of total aboveground biomass as affected by different fertilizers, UPLB, 2020 WS.

Plant height increased from early vegetative until physiological maturity but it was generally lower in the control (Figure 9).

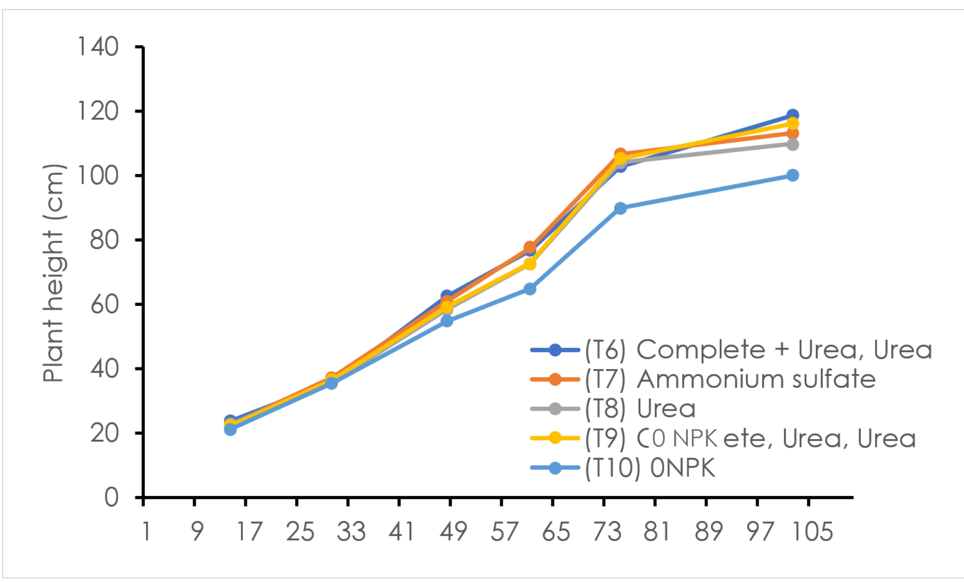

Figure 9. Dynamics of plant height as affected by different fertilizers, UPLB, 2020 WS.

Grain yields did not significantly differ among T6, T7, T8, and T9; and significantly higher than the control (Figure 10). Fertilizer source and timing of application did not affect yield.

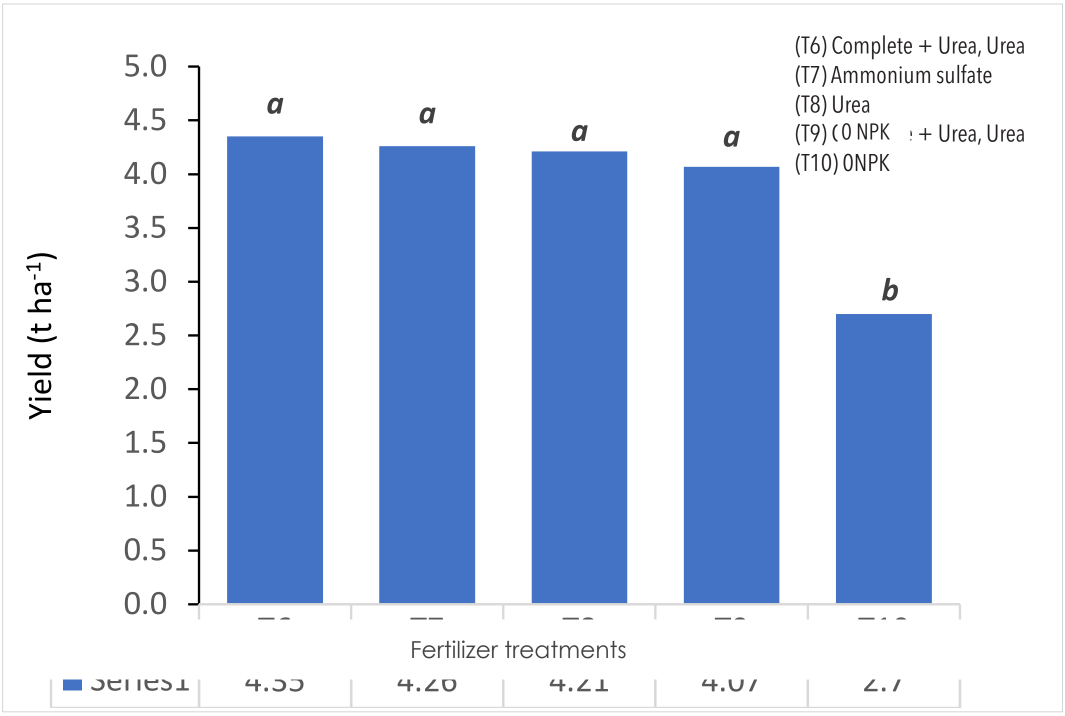

Figure 10. Grain yield of NSIC Rc420 as affected by different fertilizer N sources, UPLB, 2020 WS.

In the next section, the developed best management practices for rice, corn, and mungbean are presented. These are packaged into leaflets, one per province where experiments were conducted, to serve as guide for farmers.

Best management practices for rice in drought-prone areas in target Regions 1, 2, 3, 5, 6, 12, and CAR

Results of previous technology generation trials in 2019-2020 were analyzed and processed to develop the best management practices for mechanized dry direct-seeded rice using MP Seeder under rainfed lowland in the target regions. The practices include guidelines on land preparation, crop establishment, recommended varieties, and fertilizer/weed/harvest management. The general recommendations are:

- Good land preparation including pulverization, free of weeds and stubbles, and levelling should be done before seeding to achieve uniform seeding depth and prevent seed exposure.
- The seeding rate (SR) of 40- 60 kg ha^{-1} with seeding depth (SD) of 2-5 cm
- Use of rainfed varieties (Sahod-Ulan) or recommended varieties from DA-PhilRice/DA-RFO and LGUs
- Fertilizer recommendations will be based on the existing tools on site-specific nutrient management such as Rice Crop Manager (RCM), Bureau of Soils and Water Management (BSWM), and the DA-RFO rates.
- The total nitrogen rate provided by the tools will be the basis of calculating the proportion and timing of application (Table 19).
- Ensure the right field conditions, rate, and timing of application of the appropriate materials when using pre-emergence, and early and late post-emergence herbicides. Drain the field 1-2 weeks before the expected date of harvesting, and harvest at the right maturity.

Table 19. Nitrogen fertilizer management options.

Option	Timing of application	Type of fertilizer	% Recommended rate of total N, kg ha^{-1}
1	1st (0-10 DAS)	Complete	Apply 40%
	2nd (20-30 DAS)	Urea	Apply 30%
	3rd (45-50 DAS)	Urea	Apply 30%
2	1st (20-30 DAS)	Complete and Urea	Apply 55%
	2nd (45-50 DAS)	Urea	Apply 45%

Best management practices for corn

These were extracted from the National Cooperative Trials for corn and Site-specific Nutrient Management (SSNM)-based fertilizer recommendations from the DA. Modifications were made to fit the MP Seeder fertilizer hoppers and plates.

- Soil should be well-pulverized, weed- and stubble-free, and proper field levelling should be done before seeding to achieve uniform seeding depth and prevent seed exposure.
- Use of hybrid varieties and/or open-pollinated varieties recommended in the target areas by DA-RFO.
- Seeding rate is 16-20 kg ha^{-1} with a seeding depth of 4–6 cm using the MP Seeder.
- Nutrient management for open-pollinated and hybrid varieties has two options based on target yield.

Table 20. Recommended fertilizer rate and timing of application for OPV.

Recommended rate, NPK (kg/ha)*	Target yield (t ha^{-1})	Amount of fertilizer (bags ha^{-1})	
		Basal (0 DAE)	Side dress (25 DAE)
Option 1 130 – 40 – 40	3.0 – 5.0	5.7 (14-14-14)	3 (46-0-0)
Option 2 160 – 40 – 40	5.0 – 7.0	5.7 (14-14-14)	5.9 (46-0-0)

Table 21. Recommended fertilizer rate and timing of application for Hybrid.

Recommended rate, NPK (kg/ha)*	Target yield (t ha^{-1})	Amount of fertilizer (bags ha^{-1})	
		Basal (0 DAE)	Side dress (25 DAE)
Option 1 130 – 65 – 65	5.0 – 8.0	9.3 (14-14-14)	2.8 (46-0-0)
Option 1 200 – 65 – 65	8.0 – 12.0	9.3 (14-14-14)	5.9 (46-0-0)

- Weed management in OPV requires pre-emergence herbicide (a.i. Atrazine) at 0-4 DAS, hilling up at 25-30 DAS, and hand weeding if needed at 40-45 DAS. For hybrid, application of herbicide (a.i. Glyphosate) at 15 DAS and 35 DAE.

- Control of fall army worm (FAW) using insecticide (a.i. Chlorantranliprole) at 7 DAE with reapplication after 1 week. For seedling maggot, corn earworm, corn borer, and army worm, insecticides with active ingredient Chlorpyrifos and BMPC+Chlorpyrifos can be used.

Best management practices for mungbean

These were extracted from the Institute of Plant Breeding-National Seed Foundation and DA-Cagayan Valley Research Center (DA-CVRC) Mungbean production technology guide:

- The field should be properly levelled to minimize uneven seeding depth and prevent seed exposure.
- Use recommended varieties from DA-RFOs or MAO or Pag-asa 7, a non-shattering variety; thus, harvesting can be done efficiently.
- Seeding rate is 20 kg ha^{-1} with seeding depth of 2-5 cm; 28 N – 28 P_2O_5 – 28 K_2O kg ha^{-1} equivalent to 4 bags of complete fertilizer applied basal during crop establishment.
- Application of herbicide (a.i. fluazifop-P) when weeds are at 4-6 leaf stage, mechanical weeder, and off-barring or hilling-up can be done 15 and 25 DAP.
- Insecticides (a.i. methomyl) or trichogramma strips can be applied before flowering stage to control common pests of mungbean.
- Harvest when 95% of pods are brown (Pagasa 7, one-time harvesting) or 70% of pods turn brown or black (other varieties, with 2-3 primings).

Takeaways

1. Seeding depth

   - For mechanized dry direct seeding, it ranges from 2-cm to 5-cm. Grain yield did not vary significantly based on results of trials in 11 sites covering 7 target regions of the project with various soil types and conditions.
   - Only initial growth advantages in favor of 2-cm depth were observed in terms of tiller number and total biomass production in some experimental sites. Further physiological studies focusing on phenological growth, management and environmental factors appear important to sustain early vigor that could translate to higher grain productivity.

2. Seeding rate

   Best seeding rate is 40-60 kg ha^{-1}. Effects of 40, 60, and 120 kg seeds/ha were compared in 11 sites covering 7 target provinces of the project, and higher seedling emergence occurred under 120 kg ha^{-1}. More tillers and biomass were observed in the vegetative phase but these did not translate to higher grain yield. Yield did not significantly differ among the seeding rates, allowing the use of MP Seeder to save on seed cost.

3. The two options in applying fertilizer: i) first application of 40% of the total N recommendation from existing tools like Rice Crop Manager (RCM), applying complete fertilizer at 0-10 DAS, 2nd application of 30% of the total N using Urea at 20-30 DAS, and 3rd application of 30% of total N using Urea at 45-50 DAS; and ii) application of 55% of the total N from existing tools like RCM using complete or Urea at 20-30 DAS, followed by 2nd application of 45% of total N using Urea at 45-50 DAS.

4. Results of experiments on seeding depth, seeding rate, and nutrient management were incorporated in the integrated location-specific best management practices (land preparation to harvest) for rice in Abra, Ilocos Norte/Sur, La Union, Pangasinan, Cagayan, Tarlac, Camarines Sur, Albay, Antique, Negros Occidental, Iloilo, South Cotabato, and Sultan Kudarat.

5. Best management practices for corn were extracted from the National Cooperative Trials for corn and SSNM-based fertilizer recommendation, and fitted to the MP Seeder fertilizer hoppers and plates to come up with location-specific practices (land preparation to harvest) for Abra, Ilocos Norte/Sur, Pangasinan, Tarlac, Albay, South Cotabato, and Sultan Kudarat

6. Best management practices for mungbean were extracted from the IPB - National Seed Foundation and DA-Cagayan Valley Research Center (DA-CVRC) Mungbean production technology guide and fitted with the MP Seeder fertilizer hoppers and plates to come up with location-specific practices (land preparation to harvest) for Pangasinan, Tarlac, Batangas, and Quezon.

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3 TECHNOLOGY VERIFICATION: Validation of mechanized dry direct seeding technology package using MP Seeder (MDDS) with best management practices for rice, corn, and mungbean

Niño Paul Meynard C. Banayo • Crisanta S. Bueno • Roel R. Suralta • Emily E. Basuel • Liezel C. Peralta • Glyza M. De Gracia • Eugene L. Dingle • Eugenio P. Aquino • Ruth A. Agbisit • Rene B. Carandang • John Kenneth L. Motilla • Ronald Gregory L. Roces • Ian Marie E. Reaño • Majho V. Pamplona • Royette C. Santos • John Eric O. Abon • Elmer G. Bautista • John Mark M. Bumanglag • Mark Anthony B. Macadildig • Fennie Lyn A. Pantin • Silvestre V. Briones • Ricardo B. Casauay • Aurora M. Corales • Edwin C. Martin • Pompe C. Sta. Cruz

In this chapter, we present results of verification trials for rice, corn, and mungbean using the best management practices developed in this project as presented in Chapter 2. The key activities were field comparison of MDDS with current farmers' practices, and quantification of productivity and income gains in using MDDS. The trials were done in collaboration with our partners from state colleges and universities, DA-Regional Field Offices, and local government units.

Rice

In 2019, a total of 73 verification trials were established; 51 were under drought-prone, 14 under favorable rainfed and 8 under tail-end areas (Table 1). We struggled with early occurrence of rainfall and dry spell in Regions 1, 2 and 3 that consequently slowed down the rate of crop establishments. Based on monitoring and evaluation, 58 actual verification trials remained.

Table 1. List of actual verification trials, 2019 wet season.

Region	Provinces	Drought-Prone (DP)	Favorable rainfed (FR)	Tail-End (TE)
CAR	Abra	3	-	-
1	Ilocos Norte	3	-	-
1	Ilocos Sur	3	1	-
1	La Union	3	-	-
1	Pangasinan	-	1	2
2	Cagayan	5	-	-
3	Tarlac	3	-	-
3	Zambales	-	2	-

Table 1. (continuation)

Region	Provinces	Drought-Prone (DP)	Favorable rainfed (FR)	Tail-End (TE)
5	Albay	3	-	2
5	Camarines Sur	3	-	2
6	Antique	2	2	1
6	Iloilo	6	-	-
6	Negros Occidental	2	1	-
12	South Cotabato	2	-	1
12	Sultan Kudarat	3	2	-
Total		**41**	**9**	**8**

Varieties used for MP Seeder plots and farmers' practices for drought-prone, favorable rainfed, and tail-end areas are listed in Table 2. It was observed that farmers used irrigated varieties even in rainfed conditions.

Table 2. Varieties used under the ecosystems: drought-prone rainfed, favorable rainfed, and tail-end.

Region	Provinces	Varieties	
		MP Seeder-SU	FP-FV
Drought-Prone			
CAR	Abra	Rc 346	Rc 222
1	Ilocos Norte	Rc 420	Rc 222
1	Ilocos Sur	Rc 420	Rc 222
1	La Union	Rc 420	Rc 222
2	Cagayan	Rc 416	Rc 480
3	Tarlac	Rc 420	Rc 222
5	Albay	Rc 416	Rc 308
5	Camarines Sur	Rc 416	Rc 216
6	Antique	Rc 416	Rc 222, Rc 308
6	Iloilo	Rc 420	Rc 216
6	Negros Occidental	RC 420	Rc 402
12	South Cotabato	Rc 420	Rc 158
12	Sultan Kudarat	Rc 420	Rc 360, Rc 8
Favorable Rainfed			
1	Ilocos Sur	Rc 420	Rc 222
1	Pangasinan	Rc 420	Rc 420
3	Zambales	Rc 286	SL8 H
6	Antique	Rc 416	Rc 10
6	Negros Occidental	Rc 420	Rc 10
12	Sultan Kudarat	Rc 420	Rc 350 H, Rc 158

Table 2. (continuation)

Region	Provinces	Varieties	
		MP Seeder-SU	FP-FV
Tail-End			
1	Pangasinan	Rc 420	Rc 354, Rc 222
5	Albay	Rc 416	Rc 308
5	Camarines Sur	Rc 416	Rc 216
6	Antique	Rc 416	Rc 10
12	South Cotabato	Rc 416	Rc 27

Seeding rates from the MP Seeder delivery were determined per treatment and are presented in Table 3 for different ecosystems. Farmers' practice (FP-FV) was consistently higher than MP Seeder treatments (60 kg ha^{-1} average) in all ecosystems by 104%, 80%, and 125% under drought-prone, favorable rainfed, and tail-end areas, in that order, as averaged from all the regions.

Table 3. Mean seeding rates of MP Seeder-Sahod Ulan (SMP-SU) and Farmers' Practice-Farmers' Variety (FP-FV) in drought-prone, favorable rainfed, and tail-end areas per region, 2019 WS.

Region	Provinces	Seeding Rate (kg ha^{-1})	
		MP Seeder-SU	FP-FV
Drought-Prone			
CAR	Abra	64	200
1	Ilocos Norte	54	150
1	Ilocos Sur	58	82
1	La Union	63	80
2	Cagayan	74	120
3	Tarlac	49	150
5	Albay	56	120
5	Camarines Sur	52	120
6	Antique	67	120
6	Iloilo	62	137
6	Negros Occidental	64	90
12	South Cotabato	66	131
12	Sultan Kudarat	59	147

Table 3. (continuation)

Average		**61**	**127**
Favorable Rainfed			
1	Ilocos Sur	55	90
1	Pangasinan	46	100
3	Zambales	46	100
6	Antique	90	117
6	Negros Occidental	52	100
12	Sultan Kudarat	60	120
Average		**58**	**105**
Tail-End			
1	Pangasinan	51	120
5	Albay	51	120
5	Camarines Sur	47	120
6	Antique	51	119
12	South Cotabato	79	150
Average		**56**	**126**

With higher seeding rates used in Farmers' Practice (FP), seedling emergence counts and means were consistently higher than MP Seeder plots as shown in Table 4.

Table 4. Means of emergence count m^{-2} of MP Seeder-SU and FP-FV in drought-prone, favorable rainfed, and tail-end areas per region, 2019 WS.

Region	Provinces	Emergence count (m^{-2})	
		MP Seeder-SU	FP-FV
Drought-Prone			
CAR	Abra	231	969
1	Ilocos Norte	170	555
1	Ilocos Sur	108	261
1	La Union	126	77
2	Cagayan	223	718
3	Tarlac	87	645
5	Albay	130	123
5	Camarines Sur	55	139
6	Antique	276	56
6	Iloilo	117	341
6	Negros Occidental	99	167
12	South Cotabato	142	600
12	Sultan Kudarat	74	184

Table 4. (continuation)

Region	Provinces	Emergence count (m^{-2})	
		MP Seeder-SU	FP-FV
Favorable Rainfed			
1	Ilocos Sur	147.22	81.67
1	Pangasinan	77.22	174.67
3	Zambales	96.94	118.67
6	Antique	318.33	270
6	Negros Occidental	119.44	72
12	Sultan Kudarat	109.44	333.33
Tail-End			
1	Pangasinan	118.06	432.67
5	Albay	104.44	209.33
5	Camarines Sur	85.28	183.33
6	Antique	314.44	493.33
12	South Cotabato	164.44	872

Actual seeding depths measured from MP Seeder treatments established in various ecosystems are reflected in Table 5 to be similar to farmers' practice in most areas.

Table 5. Seeding depth of MP Seeder-SU and FP-FV in drought-prone, favorable rainfed, and tail-end areas per region, 2019 WS.

Region	Provinces	Seeding Depth (cm)	
		MP Seeder-SU	FP-FV
Drought-Prone			
CAR	Abra	2.55	3.38
1	Ilocos Norte	2.65	3.47
1	Ilocos Sur	1.87	2.43
1	La Union	2.35	3.25
2	Cagayan	2.55	2.91
3	Tarlac	3.02	4.11
5	Albay	2.83	2.36
5	Camarines Sur	2.08	2.63
6	Antique	2.49	2.73
6	Iloilo	2.09	2.78
6	Negros Occidental	4.53	4.75
12	South Cotabato	1.86	1.8
12	Sultan Kudarat	1.91	1.5

Table 5. (continuation)

Favorable Rainfed			
1	Ilocos Sur	1.84	1.62
1	Pangasinan	1.55	1.83
3	Zambales	2.97	2.24
6	Antique	1.98	2.89
6	Negros Occidental	4	4.9
12	Sultan Kudarat	2.41	1.95
Tail-End			
1	Pangasinan	1.24	2.21
5	Albay	3.09	2.38
5	Camarines Sur	1.92	2.93
6	Antique	1.96	1.12
12	South Cotabato	3.15	3.03

Average grain yields comparing the MP Seeder-SU plots and FP-FV plots from the drought-prone areas are sketched in Figure 1. MP-SU averages were higher in Ilocos Norte, Ilocos Sur, Albay, Camarines Sur, Antique, Iloilo, and Sultan Kudarat; not significantly different in La Union, Abra, Negros Occidental, and South Cotabato. Considering all sites, MP-SU grain yield was higher by 12% than FP-FV.

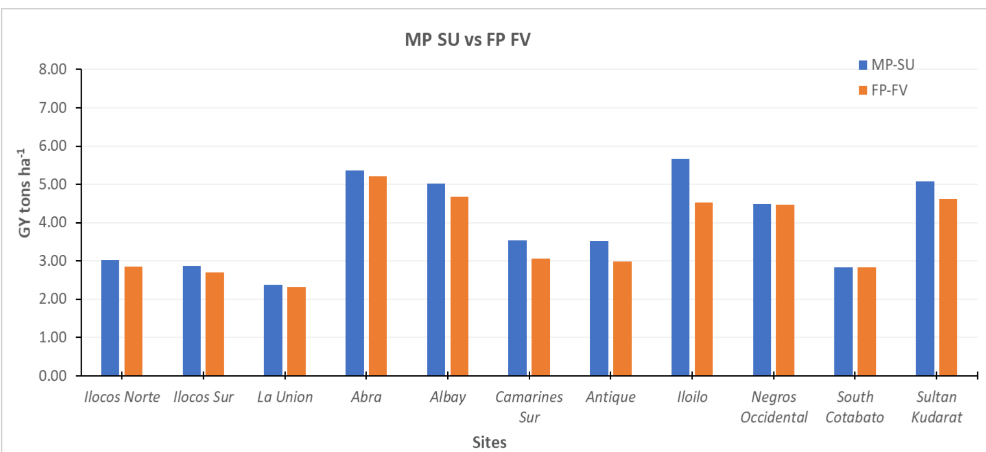

Figure 1. Comparison of MP-SU and FP-FV grain yields in drought-prone areas, 2019 WS.

Favorable Rainfed

Under favorable areas, average yields of MP-SU were higher by 18% in all the provinces (Figure 2), particularly in Negros Occidental, then Zambales and Sultan Kudarat. Lowest grain yield was observed in Pangasinan.

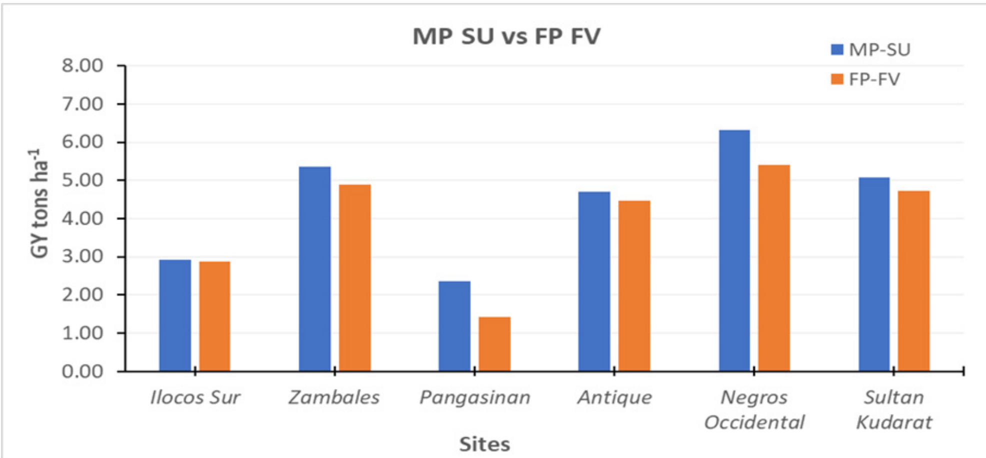

Figure 2. Comparison of MP-SU and FP-FV grain yields in favorable rainfed areas, 2019 WS.

Tail-End

Comparison of yields in the tail-end of irrigated areas is presented in Figure 3, where yield ranges from 4.39 to 4.99 t ha^{-1} in MP-SU plots against only 2.65 to 4.19 t ha^{-1}. Average MP-SU yields were higher by 30% than in FP-FV plots.

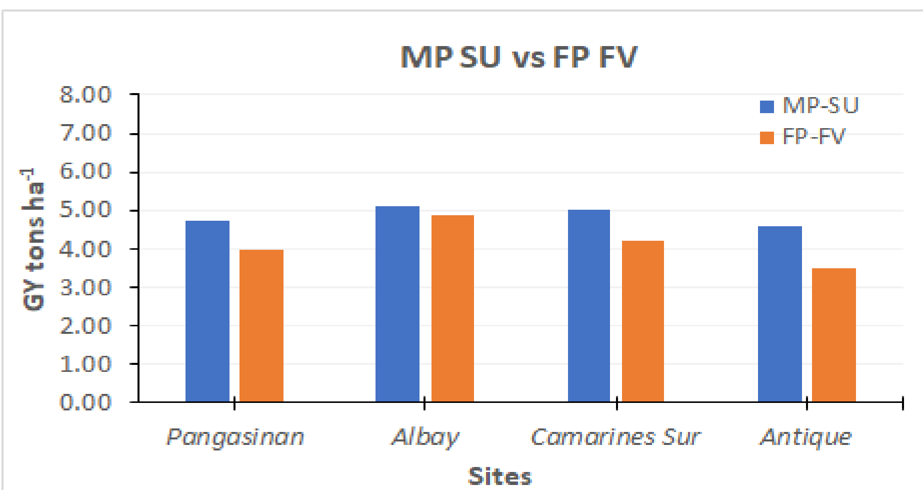

Figure 3. Comparison of MP-SU and FP-FV grain yields in tail-end areas, 2019 WS.

Sample photos of verification setup at different growth stages are carried in Figures 4, 5, 6, and 7 (Pangasinan, 2019 WS).

Figure 4. Twenty days after seeding (20 DAS)

Figure 5. Thirty-three days (33 DAS)

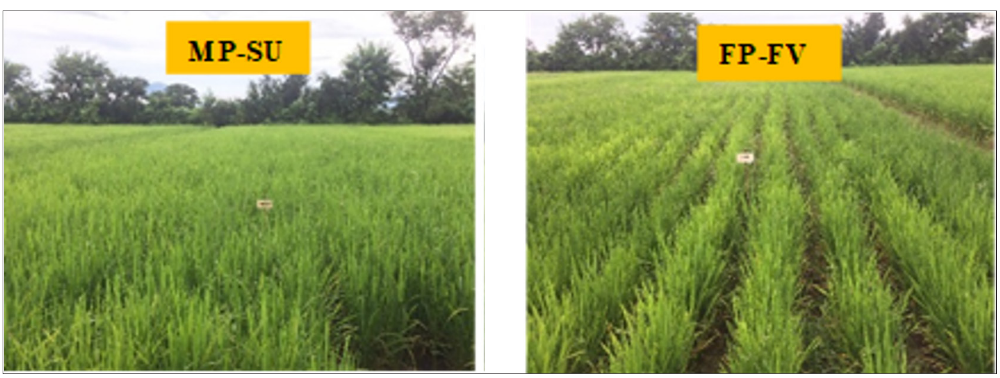

Figure 6. Booting stage

Figure 7. Physiological maturity

In 2020 WS, verification trials were established in 49 sites for 7 regions, with 3 replications. Four treatments were established in each site except in Albay and Sorsogon:

- (T1) MPS+BMP+RV_{60}: MP Seeder + Best management practice + Recommended variety (Seeding rate: 60 kg ha^{-1})
- (T2) MPS+ BMP + RV_{40}: MP Seeder + Best management practice + Recommended variety (Seeding rate: 40 kg ha^{-1})
- (T3) MPS+ BMP + FV: MP Seeder + Best management practice + farmers' variety (Seeding rate: 60 kg ha^{-1})

Fertilizer rate for treatments 1, 2, and 3 was 100 kg N, 40 kg P_2O_5, 40 K_2O ha^{-1} applied at 0-15 DAS (at 40 kg NPK ha^{-1}), at 30-35 DAS at 30 kg N ha^{-1} using urea, and at 50 DAS/PI (panicle initiation) at 30 kg N ha^{-1} using urea. Pre-emergence herbicide was applied at 0-4 DAS.

- (T4) FCEM+FMP+FV: Farmers' crop establishment method + Farmers' management practice + Farmers' variety. Seeding rate, nutrient and weed management: according to Farmers' practice.

For Bicol on-farm generation sites, three treatments were implemented using the following:

- (T1) MPS+BMP+RV_{60}: Multipurpose Seeder + Best management practice + Recommended variety (Seeding rate: 60 kg ha^{-1})
- (T2) MPS+ FMP + RV_{40}: MP Seeder + Farmers' management practice + Recommended variety (Seeding rate: 40 kg ha^{-1})
- (T3) FCEM+FMP+FV: Farmers' crop establishment method + Farmers' management practice + Farmers' variety.

Table 6 details the number of farmer-cooperators for the trials in all target regions for the validation of integrated best management practices (BMP) of the MP Seeder. Delayed crop establishment was due to the pandemic. Farmers used high seeding rates except in Albay (45-51 kg ha^{-1}).

Table 6. Established 2020 wet season on-farm verification trials for rice.

Region	Provinces	No. of farmer cooperators	Date of crop establishment	Farmers' seeding rate (kg ha^{-1})
CAR	Abra	1	July 15, 2020	196
1	Ilocos Norte	6	July 3-17, 2020	92-156
	Pangasinan	1	July 2, 2020	81
2	Cagayan	5	June 18-19, 2020; July 22, 2020	100-120
3	Tarlac	6	June 22, 2020; July 9-10, 2020	35 (hybrid); 83-250
5	Sorsogon	6	July 22-23, 2020; August 12, 2020	113-212
	Camarines Sur	4	July 25-26, 2020; August 26, 2020	71-131
	Albay	3	July 21, 2020	45-51
6	Negros Occidental	4	July 1- 9, 2020	180-217
	Iloilo	8	July 5- 10, 2020	134-258
12	Sultan Kudarat	3	May 29 – June 2, 2020	120
	South Cotabato	2	June 5, 2020; June 10, 2020	120

The growing season faced problems such as droughts and flooding that limited the number of on-farm verification trials (Table 7).

Table 7. Successful 2020 wet season on-farm verification trials for rice.

Region	Province	Drought-Prone (DP)	Favorable Rainfed (FR)	Tail-End (TE)
1	Ilocos Norte	2	-	2
1	Pangasinan	-	1	-
2	Cagayan	3	-	-
3	Tarlac	-	1	-
5	Sorsogon	4	-	-
5	Camarines Sur	3	-	-
6	Negros Occidental	1	-	3
6	Iloilo	8	-	-
12	Sultan Kudarat	1	2	-
12	South Cotabato	2	-	-
Total		**24**	**3**	**5**

Recommended varieties paired with the MP Seeder are enumerated in Table 8, corresponding to T1 and T2; farmers' varieties in T3 and T4.

Table 8. List of rice varieties for 2020 wet season verification trials.

Region	Province	Varieties			
		(T1)	(T2)	(T3)	(T4)
		MPS+BMP+ RV60	MPS+BMP+ RV40	MPS+BMP+ FV60	FCEM+FMP+ FV
Drought-Prone					
1	Ilocos Norte	NSIC Rc 420	NSIC Rc 420	NSIC Rc 222	NSIC Rc 222
2	Cagayan	NSIC Rc 416	NSIC Rc 416	NSIC Rc 480	NSIC Rc 480
6	Negros Occidental	NSIC Rc 480	NSIC Rc 480	NSIC Rc 216	NSIC Rc 216
6	Iloilo	NSIC Rc 480, NSIC Rc 426	NSIC Rc 480, NSIC Rc 426	NSIC Rc 216, Rc 346, Rc 300, Rc 27, PSB Rc 10	NSIC Rc 216, Rc 346, Rc 300, NSIC Rc 27, PSB Rc 10
12	Sultan Kudarat	NSIC Rc 420	NSIC Rc 420	NSIC Rc 400	NSIC Rc 400
12	South Cotabato	NSIC Rc 420, NSIC Rc 426	NSIC Rc 420, NSIC Rc 426	NSIC Rc 222, NSIC Rc 25	NSIC Rc 222, NSIC Rc 25
Favorable Rainfed					
1	Pangasinan	NSIC Rc 480	NSIC Rc 480	NSIC Rc 222	NSIC Rc 222
3	Tarlac	NSIC Rc 480, NSIC Rc 420	NSIC Rc 480, NSIC Rc 420	NSIC Rc 222, SL-8H	NSIC Rc 222, SL-8H
12	Sultan Kudarat	NSIC Rc 420	NSIC Rc 420	NSIC Rc 400	NSIC Rc 400
Tail-End					
1	Ilocos Norte	NSIC Rc 420	NSIC Rc 420	NSIC Rc 222	NSIC Rc 222
6	Negros Occidental	NSIC Rc 420	NSIC Rc 420	NSIC Rc 216	NSIC Rc 216

Table 9. List of rice varieties in Bicol Region, 2020 WS

Region	Province	Varieties		
		(T1)	(T2)	(T3)
		MPS+BMP	MPS+FNM	FCEM+FNM
Drought-Prone				
5	Sorsogon	NSIC Rc 480	NSIC Rc 480	NSIC Rc 416
5	Camarines Sur	NSIC Rc 480	NSIC Rc 480	NSIC Rc 480, NSIC Rc 222

The actual seeding rates used in the different treatments per province are presented in Table 10. Average rates in all sites for T1, T2, T3 and T4 are 74-kg ha^{-1}, 44-kg ha^{-1}, 74-kg ha^{-1}, and 137-kg ha^{-1}, in that order. Using the MP Seeder with 60-kg ha^{-1} in T1 and T3 saved 63 kg; for T2, seeding rate was 93 kg ha^{-1}.

Table 10. Average seeding rates of rice verification trials, 2020 WS.

Region	Provinces	Actual Seeding Rate (kg ha^{-1})			
		(T1)	(T2)	(T3)	(T4)
		MPS+BMP+ RV60	MPS+BMP+ RV40	MPS+BMP+ FV60	FCEM+FMP+ FV
Drought-Prone					
1	Ilocos Norte	76	55	72	115
2	Cagayan	76	35	69	118
6	Negros Occidental	78	33	100	205
6	Iloilo	57	43	73	198
12	Sultan Kudarat	47	37	35	120
12	South Cotabato	45	41	48	120
Favorable Rainfed					
1	Pangasinan	86	56	83	81
3	Tarlac	74	49	74	101
12	Sultan Kudarat	61	36	58	120
Tail-End					
1	Ilocos Norte	78	57	79	138
6	Negros Occidental	77	32	64	199

Actual seeding rates used in Sorsogon and Camarines Sur are identified in Table 11, where farmer's practice was higher by 80 kg ha^{-1} than the MP Seeder's plot in Sorsogon. However, in Camarines Sur, seeding rates among treatments were comparable.

Table 11. Average seeding rates of rice verification trials in Bicol Region, 2020 WS.

Region	Provinces	Actual Seeding Rate (kg ha^{-1})		
		(T1)	(T2)	(T3)
		MPS+BMP	MPS+FNM	FCEM+FNM
Drought-Prone				
5	Sorsogon	78	78	158
5	Camarines Sur	63	63	72

Seedling emergence counts at 14 DAS are presented in Tables 12 and 13. Higher seeding rates had resulted in higher seedling emergence per unit area, but the plots of T3 in Bicol were severely damaged by birds (no data in Table 13).

Table 12. Emergence counts m^{-2} of rice verification trials from the different provinces, 2020 WS.

Region	Provinces	Emergence count m^{-2}			
		(T1)	(T2)	(T3)	(T4)
		MPS+BMP+ RV60	MPS+BMP+ RV40	MPS+BMP+ FV60	FCEM+ FMP+FV
Drought-Prone					
1	Ilocos Norte	166	114	299	138
2	Cagayan	244	147	148	256
6	Negros Occidental	105	77	-	545
6	Iloilo	167	150	164	633
12	Sultan Kudarat	110	91	88	1,205
12	South Cotabato	123	117	155	1,643
Favorable Rainfed					
1	Pangasinan	251	162	263	420
3	Tarlac	203	110	148	245
12	Sultan Kudarat	100	85	106	918
Tail-End					
1	Ilocos Norte	223	154	180	128
6	Negros Occidental	82	104	104	272

Table 13. Emergence count m^{-2} of rice verification trials in Bicol Region, 2020 WS.

Region	Provinces	Emergence count m^{-2}		
		(T1)	(T2)	(T3)
		MPS+BMP	MPS+FNM	FCEM+FNM
Drought-Prone				
5	Sorsogon	144	131	-
	Camarines Sur	290	319	-

Relationship between seeding rate and seedling number is presented in Figure 8. A correlation coefficient of 0.865 was noted: the higher the seeding rate, the more the seedlings per unit area confirming the positive relationship.

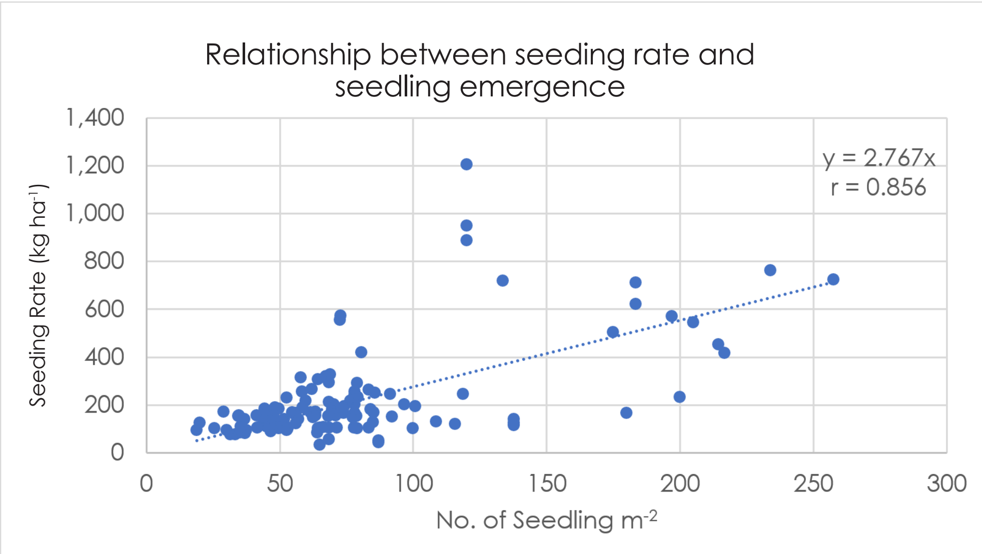

Figure 8. Relationship between seeding rate and seedling emergence in on-farm verification trials, 2020 WS.

Grain yields obtained from the different MPS+BMP plots (T1, T2, T3) in comparison with the farmers' crop establishment and management are presented in Table 14. Higher yields were obtained from T1, T2, and T3 over T4 (farmers' practice) in Ilocos Norte, Iloilo and Sultan Kudarat under the drought-prone ecosystem, but Cagayan and South Cotabato yielded higher in T4. T1 yielded slightly higher than T4 under the favorable rainfed ecosystem. In the tail-end, MPS+BMP plots gave higher yields than T4.

Table 14. Grain yields of rice verification trials, 2020 WS

Region	Province	GY (kg ha^{-1})			
		(T1)	(T2)	(T3)	(T4)
		MPS+BMP+ RV60	MPS+BMP+ RV40	MPS+BMP+ FV60	FCEM+FMP+ FV
Drought-Prone					
1	Ilocos Norte	4,356	3,634	4,922	3,588
2	Cagayan	1,656	1,716	1,791	1,864
6	Negros Occidental	3,611	2,556	-	2,590
6	Iloilo	5,728	5,088	4,625	4,027
12	Sultan Kudarat	4,570	4,177	3,307	3,493
12	South Cotabato	1,628	1,792	3,465	3,073
Favorable Rainfed					
1	Pangasinan	4,133	3,990	-	-
3	Tarlac	3,655	2,857	3,242	3,375
12	Sultan Kudarat	3,603	3,650	5,875	5,193
Tail-End					
1	Ilocos Norte	3,607	2,358	3,414	2,940
6	Negros Occidental	5,047	4,106	4,300	3,700

Higher crop establishment cost was incurred by T4, compared with T1 and T2. Seed and labor costs were higher in T4 (Table 15). Savings in seed cost for T1 compared with T4 were PhP 2,891, PhP 6,495 and PhP 4,161 in drought-prone, rainfed, and tail-end, in that order.

Table 15. Crop establishment costs of four treatments in drought-prone, favorable rainfed, and tail-end areas per region, 2020 WS.

Province	Seed Cost (PhP)				Crop Establishment Labor Cost				Total Crop Establishment Cost			
	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60+ FV	(T4) FP+ FV	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60+ FV	(T4) FP+ FV	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60+ FV	(T4) FP+ FV
Drought-Prone												
Ilocos Norte (2)	2,040	1,360	2,760	5,290	1,800	1,800	1,800	2,750	3,840	3,160	4,560	8,040
Cagayan (4)	2,040	1,360	2,760	4,681	1,800	1,800	1,800	2,200	3,840	3,160	4,560	6,881
Negros Occ. (1)	2,040	1,360	-	5,600	1,800	1,800	-	4,150	3,840	3,160	-	9,750
Iloilo (8)	2,040	1,360	1,643	4,153	1,800	1,800	1,800	2,125	3,840	3,160	3,443	6,278
Sultan Kudarat (1)	2,040	1,360	1,500	3,000	1,800	1,800	1,800	2,510	3,840	3,160	3,300	5,510
South Cotabato (2)	2,040	1,360	2,040	4,080	1,800	1,800	1,800	2,964	3,840	3,160	3,840	7,044
Mean	**2,040**	**1,360**	**2,388**	**4,931**	**1,800**	**1,800**	**1,800**	**2,806**	**3,840**	**3,160**	**4,188**	**7,737**
Favorable Rainfed												
Pangasinan (1)	2,040	1,360	-	-	1,800	1,800	-	-	3,840	3,160	-	-
Tarlac (2)	2,040	1,360	22,800	12,990	1,800	1,800	1,800	1,032	3,840	3,160	24,600	14,022
Sultan Kudarat (2)	2,040	1,360	2,040	4,080	1,800	1,800	1,800	2,510	3,840	3,160	3,840	6,590
Mean	**2,040**	**1,360**	**12,420**	**8,535**	**1,800**	**1,800**	**1,800**	**1,771**	**3,840**	**3,160**	**14,220**	**10,306**
Tail-End												
Ilocos Norte (2)	2,040	1,360	2,760	6,348	1,800	1,800	1,800	2,750	3,840	3,160	4,560	9,098
Negros Occ. (3)	2,040	1,360	1,880	6,053	1,800	1,800	1,800	2,433	3,840	3,160	3,680	8,487
Mean	**2,040**	**1,360**	**2,320**	**6,201**	**1,800**	**1,800**	**1,800**	**2,592**	**3,840**	**3,160**	**4,120**	**8,792**

Total production cost was consistently higher under T4 (farmers' practice) compared with MP Seeder-established plots. T4 cost Php 4,310, which is 12.4 % higher than T1. Net income was higher in T1 compared with T4 by Php 10,850, Php 4,956 and Php 22,931 in drought-prone, favorable rainfed, and tail-end ecosystems, respectively. The cost to produce a kilo of *palay* is lower in T1 compared with T4 in all ecosystems (Table 16).

Table 16. Total production costs, gross and net incomes, and cost to produce 1kilo of *palay* under four treatments in drought-prone, favorable rainfed, and tail-end areas per region, 2020 WS.

Province	Total Production Cost (PhP)				Gross Income				Net Income				Cost to produce 1kilo			
	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60 +FV	(T4) FP +FV	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60 +FV	(T4) FP +FV	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60 +FV	(T4) FP +FV	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60 +FV	(T4) FP +FV
Drought-Prone																
Ilocos Norte (2)	41,613	39,397	43,536	48,570	74,054	61,772	83,677	60,992	32,441	22,374	40,142	12,422	10.43	11.02	8.99	13.69
Cagayan (4)	23,828	23,219	24,177	30,539	22,263	22,978	23,585	23,237	-1,564	-241	-592	-7,303	16.10	15.13	15.58	19.46
Negros Occ. (1)	35,233	31,650	-	36,082	45,139	31,944	-	32,372	9,906	295	no data	-3,710	10.03	12.93	-	14.17
Iloilo (8)	36,693	35,287	36,348	36,126	75,022	66,514	59,989	52,589	38,328	31,227	23,641	16,463	6.74	7.47	9.65	10.73
Sultan Kudarat (1)	20,708	25,388	24,553	26,913	63,980	58,473	46,293	48,907	43,272	33,085	21,740	21,994	4.55	6.17	7.47	7.92
South Cotabato (2)	24,547	27,121	29,943	30,251	26,053	28,667	55,440	49,173	1,506	1,545	25,497	18,922	15.28	15.67	8.73	10.05
Mean	30,437	32,388	31,711	34,747	51,085	45,058	53,797	44,545	20,648	14,714	22,086	9,798	10.52	11.40	10.08	12.67
Favorable Rainfed																
Pangasinan (1)	31,015	30,192	-	-	51,667	49,875	-	-	20,651	19,683	-	-	7.69	7.67	-	-
Tarlac (2)	29,087	27,640	48,194	35,703	43,860	34,280	23,200	21,660	14,773	6,640	-24,994	-14,043	10.56	9.94	16.67	11.05
Sultan Kudarat (2)	25,435	24,328	27,092	28,285	50,447	51,100	82,250	72,707	25,011	26,772	55,158	44,421	7.30	6.83	4.81	5.84
Mean	28,513	27,387	37,643	31,994	48,658	45,085	52,725	47,183	20,145	17,698	15,082	15,189	8.52	8.15	10.74	8.45
Tail-End																
Ilocos Norte (2)	38,973	35,638	39,283	47,003	61,322	40,078	58,041	49,975	22,349	4,440	18,758	2,973	10.92	15.82	11.75	18.35
Negros Occ. (3)	31,228	31,883	32,405	36,188	74,016	59,728	61,594	52,489	42,787	27,845	29,190	16,301	6.80	8.37	8.01	10.28
Mean	35,101	33,760	35,844	41,595	67,669	49,903	59,818	51,232	32,568	16,143	23,974	9,637	8.86	12.09	9.88	14.31

The amount of fertilizer applied was higher under T4 (Farmers' practice) in Ilocos Norte, Cagayan and Tarlac; higher under T1 in Negros Occ., Iloilo, Sultan Kudarat and South Cotabato (Table 17).

Table 17. Fertilizer costs of four treatments in drought-prone, favorable rainfed, and tail-end areas per region, 2020 WS.

Province	Fertilizer Material Cost (PhP)				Fertilizer Labor Cost				Total Fertilizer Cost			
	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60+ FV	(T4) FP+ FV	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60 +FV	(T4) FP+ FV	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60 +FV	(T4) FP+ FV
Drought-Prone												
Ilocos Norte (2)	9,560	9,560	9,560	13,950	2,100	2,100	2,100	2,100	11,660	11,660	11,660	16,050
Cagayan (4)	8,928	8,928	8,928	13,705	2,100	2,100	2,100	1,400	11,028	11,028	11,028	15,105
Negros Occ. (1)	8,632	8,632	-	6,380	750	750	-	750	9,382	9,382	-	7,130
Iloilo (8)	9,406	9,406	9,406	8,250	1,583	1,583	1,583	1,189	10,989	10,989	10,989	9,439
Sultan Kudarat (1)	8,010	8,010	8,010	7,950	1,800	1,800	1,800	1,800	9,810	9,810	9,810	9,750
South Cotabato (2)	8,770	8,770	8,770	6,225	900	900	900	1,050	9,670	9,670	9,670	7,275
Mean	8,884	8,884	8,935	9,410	1,539	1,539	1,697	1,381	10,423	10,423	10,631	10,791
Favorable Rainfed												
Pangasinan (1)	9,560	9,560	-	-	900	900	-	-	10,460	10,460	-	-
Tarlac (2)	9,270	9,270	9,270	7,750	1,260	1,260	1,260	990	10,530	10,530	10,530	8,740
Sultan Kudarat (2)	8,550	8,550	8,550	7,361	1,350	1,350	1,350	1,650	9,900	9,900	9,900	9,011
Mean	9,127	9,127	8,910	7,556	1,170	1,170	1,305	1,320	10,297	10,297	10,215	8,876
Tail-End												
Ilocos Norte (2)	9,560	9,560	9,560	14,450	2,100	2,100	2,100	1,400	11,660	11,660	11,660	15,850
Negros Occ. (3)	8,531	8,531	8,531	8,667	1,150	1,150	1,150	1,150	9,681	9,681	9,681	9,817
Mean	9,046	9,046	9,046	11,558	1,625	1,625	1,625	1,275	10,671	10,671	10,671	12,833

Closely similar pesticide and labor costs incurred among the four treatments are presented in Table 18.

Table 18. Pesticide costs of four treatments in drought-prone, favorable rainfed, and tail-end areas per region, 2020 WS.

Province	Pesticide Material Cost (PhP)				Pesticide Labor Cost				Total Pesticide Cost			
	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60+ FV	(T4) FP+ FV	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60+ FV	(T4) FP+ FV	(T1) MP60+ BMP	(T2) MP40+ BMP	(T3) MP60+ FV	(T4) FP+ FV
Drought-Prone												
Ilocos Norte (2)	5,756	5,756	5,756	5,756	2,100	2,100	2,100	2,100	7,856	7,856	7,856	7,856
Cagayan (4)	2,463	2,463	2,285	2,285	1,750	1,750	1,575	1,575	4,213	4,213	3,860	3,860
Negros Occ. (1)	3,580	3,580	-	3,580	1,500	1,500	-	1,500	5,080	5,080	-	5,080
Iloilo (8)	3,163	3,163	3,163	3,163	1,279	1,279	1,279	1,279	4,441	4,441	4,441	4,441
Sultan Kudarat (1)	2,850	2,850	2,850	2,850	1,800	1,800	1,800	1,800	4,650	4,650	4,650	4,650
South Cotabato (2)	4,740	4,740	4,740	4,740	1,650	1,650	1,650	1,650	6,390	6,390	6,390	6,390
Mean	3,759	3,759	3,759	3,729	1,680	1,680	1,681	1,651	5,438	5,438	5,439	5,380
Favorable Rainfed												
Pangasinan (1)	3,682	3,682	-	-	900	900	-	-	4,582	4,582	-	-
Tarlac (2)	2,900	2,900	2,900	2,900	840	840	840	840	3,740	3,740	3,740	3,740
Sultan Kudarat (2)	2,575	2,575	2,575	2,575	1,200	1,200	1,200	1,200	3,775	3,775	3,775	3,775
Mean	3,052	3,052	2,738	2,738	980	980	1,020	1,020	4,032	4,032	3,758	3,758
Tail-End												
Ilocos Norte (2)	4,633	4,633	4,633	4,633	2,100	2,100	2,100	2,100	6,733	6,733	6,733	6,733
Negros Occ. (3)	4,357	4,357	4,357	4,357	1,100	1,100	1,100	1,100	5,457	5,457	5,457	5,457
Mean	4,495	4,495	4,495	4,495	1,600	1,600	1,600	1,600	6,095	6,095	6,095	6,095

To verify the MP Seeder technology, on-farm trials for rice were established in 7 provinces (Ilocos Norte, Pangasinan, Tarlac, Camarines Sur, Sorsogon, Iloilo, and South Cotabato) in 2021 to compare MP Seeder + BMPs and farmers' practice. Recommended and farmers' varieties established in each site are identified in Table 19. Two treatments were established with 3 replications:

- MPS Technology – MP Seeder + Best management practice + Recommended variety at 60 kg ha^{-1} seeding rate
- Farmers' Practice – Farmers' crop establishment method + Farmers' management practice + Farmers' variety

Table 19. Recommended and farmers' varieties used in each site.

Region	Province	Varieties	
		MPS Technology	Farmers' Practice
1	Ilocos Norte (IN)	NSIC Rc 420	NSIC Rc 216, GSR12, Longping 2096H
1	Pangasinan (PNG)	FS 480	CS160, CS222,
3	Tarlac (TLC)	FS 480	CS420, CS436, CS408, NSIC Rc222, CS152, CS160
5	Camarines Sur (CS)	NSIC Rc 480	NSIC Rc480
5	Sorsogon (SOR)	NSIC Rc 480	NSIC Rc480
6	Iloilo (ILO)	NSIC Rc 420, NSIC Rc 480, NSIC Rc 416	NSIC Rc 416, Rc 216, Rc 426, Rc 480, Rc 18
12	South Cotabato (SC)	NSIC Rc 416	NSIC Rc 420

The average seeding rates per province are presented in Table 20. MP Seeder rates ranged from 51.9 to 68.7 kg ha^{-1} while Farmers' Practice ranged from 80.0 to 201.2 kg ha^{-1}. The recommended seeding rate of 60 kg ha^{-1} was affected by land preparation and soil type resulting in large variation of delivery by the MP Seeder.

Table 20. Average seeding rates of rice verification trials, 2021 WS.

Region	Province	Seeding rate (kg ha^{-1})	
		MPS Technology	Farmers' Practice
1	Ilocos Norte (IN)	64.1	85.0
1	Pangasinan (PNG)	51.9	130.2
3	Tarlac (TLC)	61.5	171.0
5	Camarines Sur (CS)	68.7	80.1
5	Sorsogon (SOR)	48.5	80.0
6	Iloilo (ILO)	62.6	201.2
12	South Cotabato (SC)	53.3	100.0

Figure 9 points to higher grain yields in the MP Seeder plots (T1) compared to Farmers' practice plots (T2) in all provinces. T1 yields in four provinces (IN, ILO, PNG, and TLC) ranged from 4.1 to 4.7 tons ha^{-1}; IN and PNG average yields were 32% higher than T2 plots; those of ILO and TLC were 17% higher than T2 plots. Sorsogon and Camarines Sur had lower yields but were still 46% and 10% higher compared with T2 plots. In South Cotabato, yield in T1 plots was 25% higher than T2 plots.

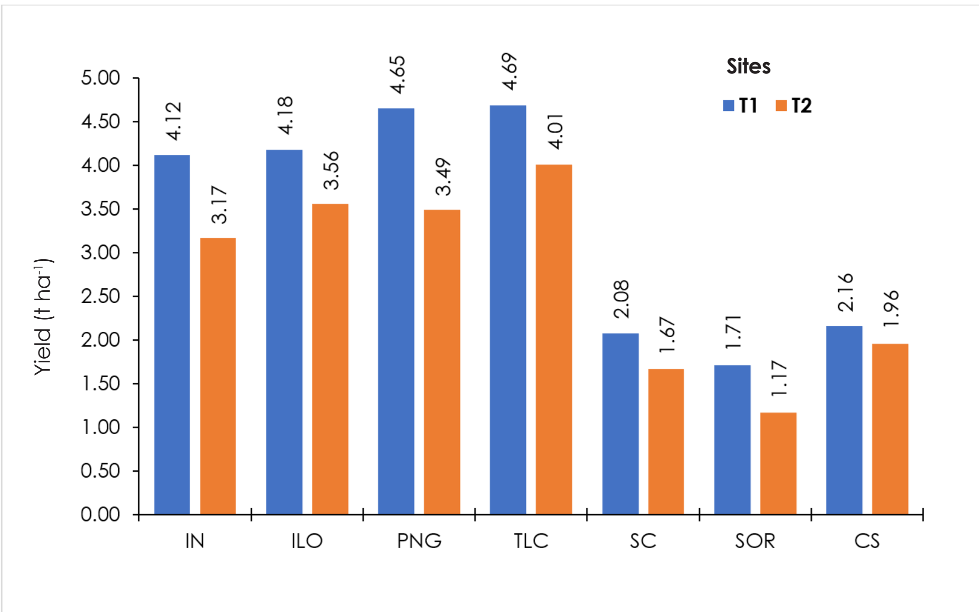

Figure 9. Grain yield of rice in T1 (MPS Technology) and T2 (Farmers' Practice) plots in 2021 WS.

Corn

During the 2020 DS, 29 corn verification trials were conducted in Regions 1, 2, 3, 5, 6 and CAR; 5 trials in Region 12 were established in June 2020. Provinces per region are presented in Table 21. Three treatments were implemented with 3 replications:

- (T1) MPS+BMP +RHV - Multipurpose Seeder + Best management practice + Recommended hybrid variety.
- (T2) MPS+FMP+RHV - Multipurpose Seeder + Farmer's management practice + Recommended hybrid variety.
- (T3) FCEM+FMP-FV – Farmers' crop establishment method + Farmers' management practice + Farmers' variety.

The recommended hybrid corn variety (RHV), NK6410 Btgr, was planted in T1 and T2 except in Abra where open-pollinated variety (OPV) was used. Row spacing of MP Seeder during seeding was 60 cm. Basal complete fertilizer at 65 kg N, 65 kg P_2O_5, 65 K_2O rate was applied in T1 using the fertilizer hoppers of the MP Seeder. Sidedress was applied at 25 DAE using urea at 65 kg N in T1. Glyphosate herbicide was applied in T1 at 15 days after seeding (DAS) and 35 DAS to control weeds. Crop care and nutrient management for T2 and T3 were based on the farmers' management practices (FMP).

Data were gathered at various growth stages and actual grain yields were collected at physiological maturity. The pandemic prevented data collection of other parameters of the trials.

Table 21. List of corn verification trials for 2020 DS.

Region	Province	No. of Farmer Cooperators	Date of Crop Establishment
CAR	Abra	3	December 12, 2019
1	Ilocos Sur	3	January 31, 2020
1	Ilocos Norte	3	January 28-29, 2020
1	Pangasinan	3	November 26, 2019; February 7-11, 2020
2	Cagayan	7	January 13-16, 2020
3	Tarlac	3	December 19-23, 2019
5	Albay	4	January 15-16, 2020
6	Iloilo	3	January 27-28, 2020
12	Sultan Kudarat	3	May 27-28, 2020
12	South Cotabato	2	June 5-10, 2020
TOTAL		**34**	

The actual seeding rates per province during crop establishment appear in Table 22. The average MP Seeder rate ranged from 16 to 23 kg ha^{-1} while FP ranged from 12 to 24 kg ha^{-1}. Fertilizer rates in FMP (Table 23) were lower than the MP Seeder plots for Ilocos Norte (ILN), Ilocos Sur (ILS), Abra (ABR) and Albay (ALB).

Table 22. Average seeding rates of corn verification trials, 2020 DS.

Province	Seeding Rate (kg ha^{-1})		
	MPS+BMP+RHV	MPS+FMP+RHV	FCEM+FMP+FV
	T1	T2	T3
Abra	19.1	21.0	11.9
Ilocos Sur	15.4	19.7	19.9
Ilocos Norte	18.9	23.0	24.1
Pangasinan	19.3	19.1	19.5
Tarlac	19.2	16.2	16.7
Albay	23.2	21.9	18.8

The amounts of fertilizer applied by farmers (T3) are detailed in Table 23, where Pangasinan had the highest; lowest in Ilocos Sur.

Table 23. Farmers' fertilizer rates applied in T2 and T3.

Province	Fertilizer Rate (kg ha^{-1})		
	Total N	Total P_2O_5	Total K_2O
Abra	133-253	7-40	7-40
Ilocos Sur	39-120	28-42	28-42
Ilocos Norte	115-150	0-35	0-35
Pangasinan	150-205	35-42	35-42
Tarlac	106-149	14-21	14-21
Albay	109-166	0-63	0-63

Figure 10 paints higher grain yields in the MP Seeder plots (T1 and T2) compared with FP plot (T3) in Ilocos Norte, Ilocos Sur, Abra and Albay. Yields were superior by 120%, 45%, 18%, and 52% in T1 compared with T3 in these sites.

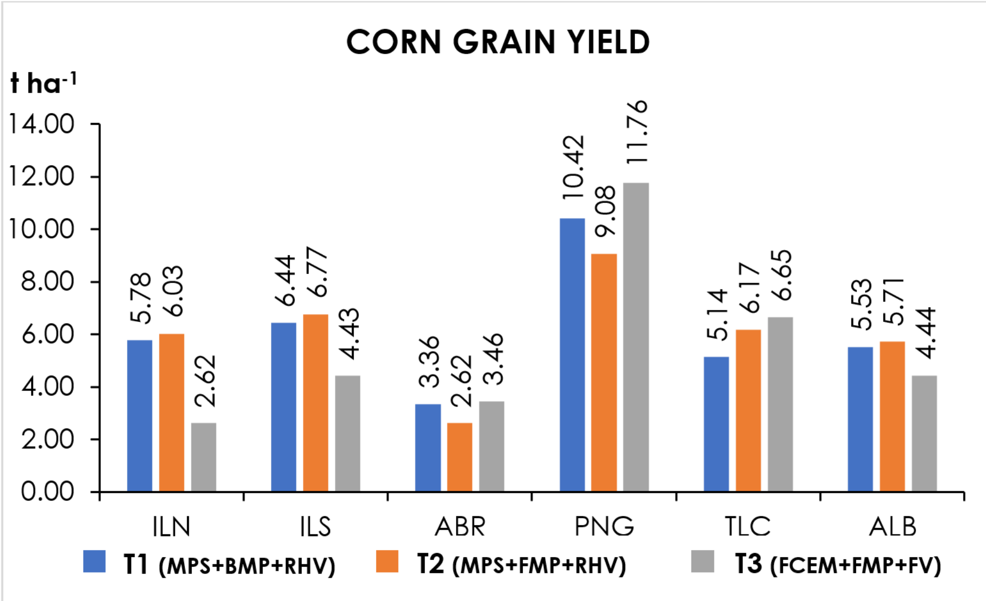

Figure 10. Corn grain yield of T1, T2, and T3 from different provinces for 2020 DS.

Crop establishment cost (labor and seed) was significantly reduced by 36% in Ilocos Sur, 28% in Abra, and by 20% in Pangasinan using the MP Seeder compared with FP (T1 vs T3), while higher cost was observed with T1 in Ilocos Norte, Tarlac and Albay (Figure 11).

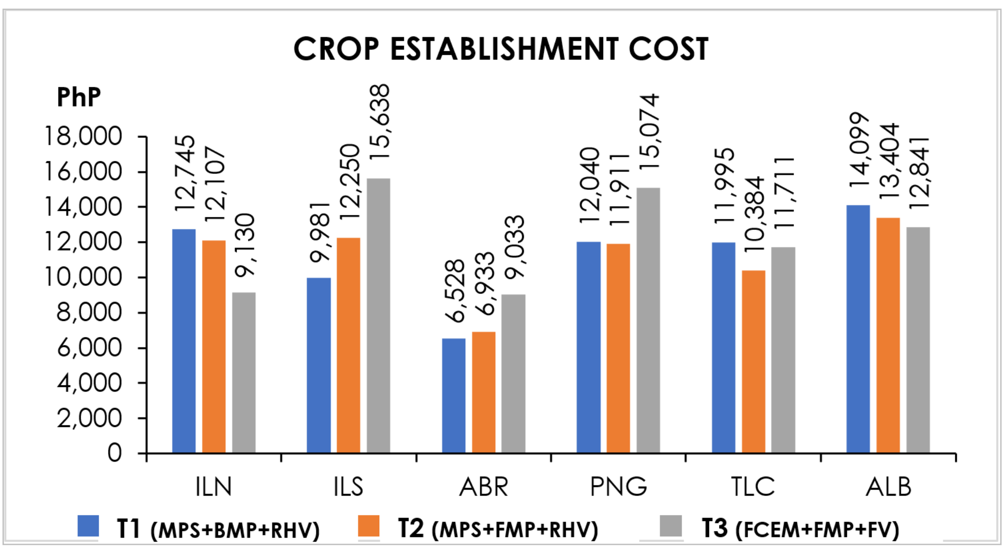

Figure 11. Corn crop establishment cost of T1, T2, and T3 from different provinces for 2020 DS.

Gross income was higher with T1 compared with T3 in Ilocos Norte, Ilocos Sur, Abra and Albay (Figure 12). The same is true with grain yield, and the net income from T1 was much higher compared with T3 in most provinces (Fig 13). In Pangasinan and Tarlac, T3 was higher compared with T1 due to higher yield.

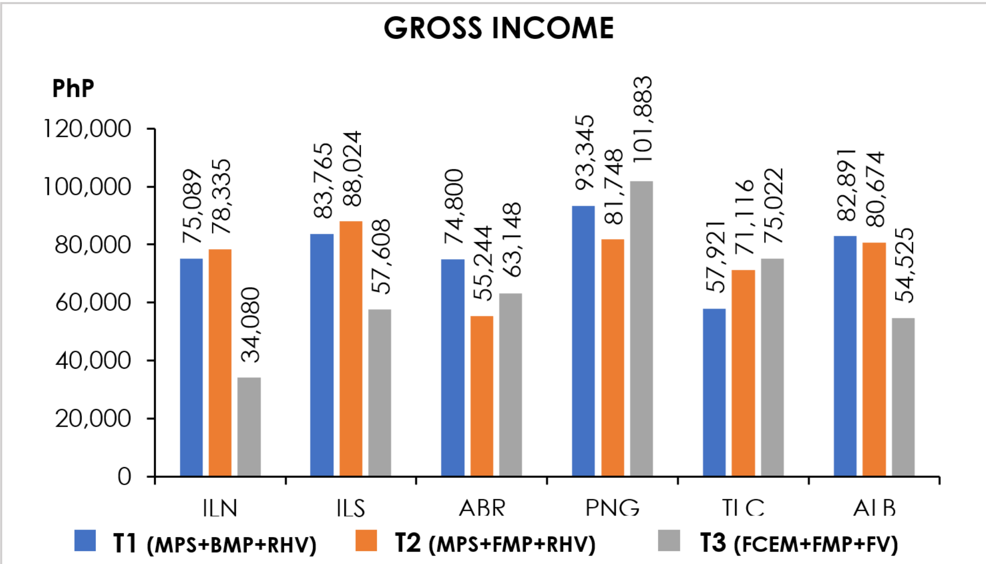

Figure 12. Corn gross income of T1, T2, and T3 from different provinces for 2020 DS.

Net income was highest with T2 in Ilocos trailed by T1; both treatments were MPS-established plots (Figure 13). Yet, net income was higher with T3 in Pangasinan and Tarlac.

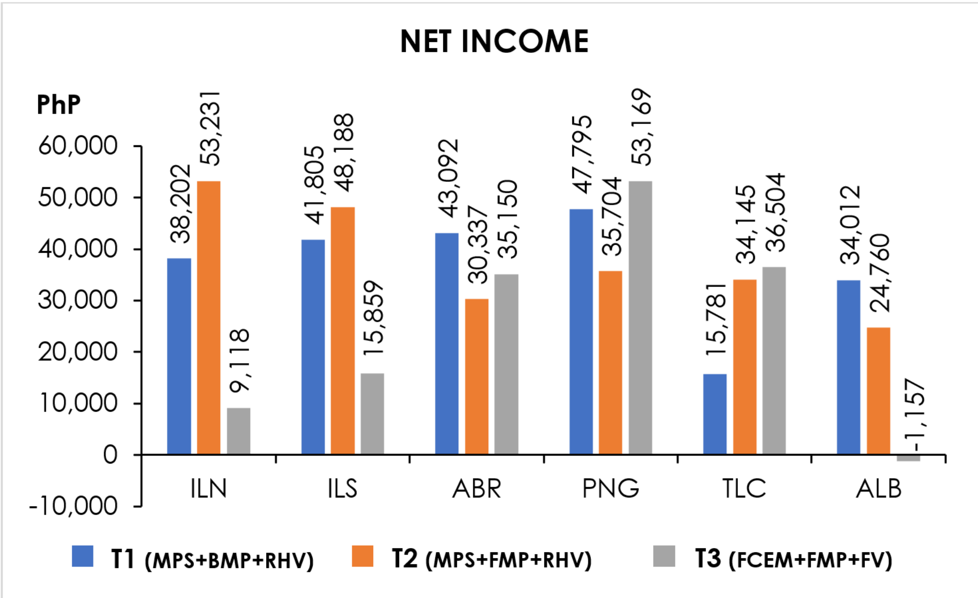

Figure 13. Corn net income of T1, T2, and T3 from different provinces for 2020 DS.

In 2021 dry season, on-farm trials of corn were established in 13 provinces (Ilocos Norte, Pangasinan, Cagayan, Tarlac, Camarines Sur, Albay, Sorsogon, Iloilo, Negros Occidental, Sultan Kudarat, South Cotabato, Batangas, Quezon) to compare and contrast MP Seeder + BMPs and farmers' practice. Two treatments were put up with 3 replications:

- (T1) MPS Technology – MP Seeder + Best management practice (Hybrid = 130 N-65 P_2O_5 -65 K_2O kg ha^{-1}; OPV and other non-Btgr = 110 N-40 P_2O_5 -40 K_2O kg ha^{-1}) + Recommended hybrid variety
- (T2) Farmers' Practice – Farmers' crop establishment method + Farmers' management practice + Farmers' variety

The recommended hybrid corn variety (RHV), NK6410 Btgr, was planted in all sites except in Batangas with Open-pollinated variety (OPV) UPLB Lagkitan and Sorsogon with hybrid sweet corn. Row spacing of MP Seeder during seeding was 60 cm.

In hybrid corn, 9.3 bags ha^{-1} of basal complete fertilizer (65 N-65 P_2O_5 -65 K_2O kg ha^{-1}) were applied during crop establishment using fertilizer plates and hoppers of the MP Seeder. At 25 days after emergence (DAE), 2.8 bags ha^{-1} of urea (65 N kg ha^{-1}) were applied as sidedress. Glyphosate herbicide was applied in T1 and T2 at 15 days after seeding (DAS) and 35 DAS to control weeds.

In OPV and hybrid sweet corn, 5.7 bags ha^{-1} of complete fertilizer (40 N-40 P_2O_5 -40 K_2O kg ha^{-1}) were applied as basal during crop establishment using fertilizer plates and hoppers of the MP Seeder. At 25 DAE, 3.0 bags ha^{-1} of sidedress urea (70 N kg ha^{-1}) were applied. Pre-emergence herbicide containing atrazine was applied at 0-4 DAS. Hilling-up after sidedress at 25 DAE and hand weeding after 2 weeks were done to control weeds.

Crop establishment dates of corn at each site are enumerated in Table 24, most of which are from November 2020 to early March 2021. Region 12 (Sultan Kudarat and South Cotabato) established April 2021 due to travel restrictions caused by the pandemic.

Table 24. Crop establishment of corn verification trials in 2021 DS.

Region	Province	Date of Crop Establishment
1	Ilocos Norte	November 24, 2020 - December 2, 2020
1	Pangasinan	November 18, 2020 - December 4, 2020
2	Cagayan	November 25, 2020 - January 13, 2021
3	Tarlac	November 24, 2020 - December 4, 2020
4A	Batangas	December 3, 2020
4A	Quezon	December 17, 2020
5	Camarines Sur	February 17- 18, 2021
5	Albay	February 16, 2021 - March 7, 2021
5	Sorsogon	January 16, 2021
6	Negros Occidental	December 1-5, 2020
12	Sultan Kudarat /South Cotabato	April 13-16, 2021

The average seeding rates ranged from 15.3 to 21.9 kg ha^{-1} (MP Seeder) and 13.3 – 42.9 kg ha^{-1} (Farmers) (Table 25). The highest rates were recorded in Negros Occidental (42.9 kg ha^{-1}) and Sultan Kudarat (30.3 kg ha^{-1}) using hybrid corn variety.

Table 25. Average seeding rates of corn verification trials in 2021 DS.

Province	Seeding rate (kg ha^{-1})	
	MPS Technology	Farmers' Practice
Ilocos Norte	19.4	18.7
Cagayan	15.4	24.3
Camarines Sur	20.2	13.3
Albay	17.5	20.1
Sorsogon	17.7	28.5
Negros Occidental	19.4	42.9
Sultan Kudarat	21.9	30.3
Pangasinan	20.3	23.6
Tarlac	17.6	23.4
Batangas	15.3	15.2
Quezon	18.8	25.7

Farmers' fertilizer rates (T2) are summarized in Table 26. Nitrogen ranged 65-207 kg ha^{-1} in hybrid corn (Btgr) and 74-75 kg ha^{-1} in non-Btgr corn. Lower application of P_2O_5 and K_2O was observed in FP across sites compared with T1.

Table 26. Farmers' fertilizer rates applied in FCEM + FMP + FV.

Corn Variety	Provinces	Fertilizer Rate, kg ha^{-1}		
		Total N	Total P_2O_5	Total K_2O
	Ilocos Norte	115-190	0-21	0-21
	Pangasinan	97-146	28-40	17-28
	Cagayan	131	61	21
	Tarlac	148-207	28-59	0-56
Hybrid corn (Btgr)	Albay	65-115	11-14	11-14
	Camarines Sur	166	28	28
	Negros Occidental	166	28	28
	Sultan Kudarat	68-122	24-34	14
	Quezon	166	28	28
White corn (OPV)	Batangas	75	17.5	17.5
Hybrid sweet corn	Sorsogon	74	28	28

Figure 14 attests to grain yields in the MP Seeder Technology being 63% higher than Farmers' Practice in all provinces.

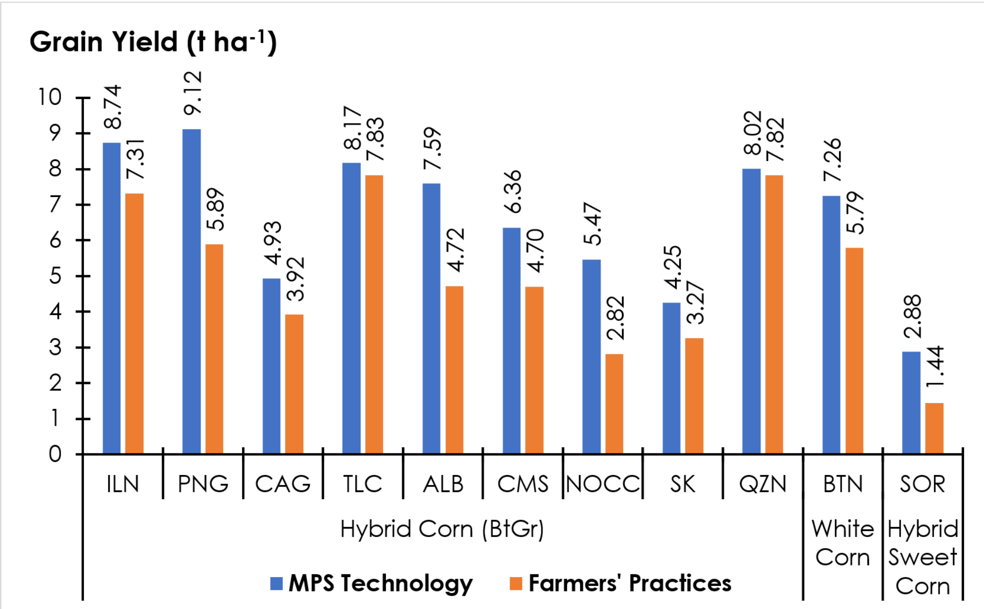

Figure 14. Grain yield of corn under two treatments, 2021 DS.

Mungbean

In 2021 DS, farm trials for mungbean were established in 4 provinces (Pangasinan, Tarlac, Quezon, and Batangas) to optimize the MP Seeder with developed BMPs and farmers' practice using the varieties Australian and Pag-asa 7. During crop establishment, 4 bags ha^{-1} of basal complete fertilizer (28 N - 28 P_2O_5 -28 K_2O kg ha^{-1}) were applied using the fertilizer hoppers of the MP Seeder.

Data on actual seeding rates and grain yields were collected during crop establishment and at physiological maturity, respectively.

Average seeding rates per province detailed in Table 27 show that MP Seeder ranged from 12 to 27 kg ha^{-1} while FP ranged from 20 to 29 kg ha^{-1}. The recommended seeding rate of 20 kg ha^{-1} was affected by land preparation and soil type resulting in large variation of delivery by MP Seeder during the initial trials in dry season.

Table 27. Average seeding rates of mungbean verification trials, 2021 DS.

Province	Seeding rate (kg ha^{-1})	
	MPS+BMP (T1)	FCEM+FMP (T2)
Pangasinan	14.9	29.2
Tarlac	22.9	26.1
Batangas	27.5	20.0
Quezon	11.9	20.0

Modifications were made in the machine as well as in its operation to address issues on soil type and land preparation in different sites. Mungbean crops were established to test the seed delivery in Quezon (May 31) and Batangas (June 15). Table 28 shows that seeding rate delivered using MP Seeder ranged 19.4 – 25.1 kg ha^{-1}. Recommended seeding rate and row spacing using MP Seeder are being optimized to maximize the potential yield for a given site.

Table 28. Average seeding rates of mungbean verification trials, 2021 WS.

Province	Seeding rate (kg ha^{-1})	
	MPS+BMP (T1)	FCEM+FMP (T2)
Batangas	19.44	20.0
Quezon	25.1	20.0

Higher population density arising from modified row spacing (40 cm) in MP Seeder establishment might be needed to further increase density resulting in more grain yield per unit area.

Table 29 banners higher grain yields in the MP Seeder plot (T1) compared with FP plot (T2) in all provinces.

Table 29. Grain yields of mungbean in two treatments.

Region	Province	GY (kg ha^{-1})	
		(T1) MPS + BMP	(T2) FCEM + FMP
1	Pangasinan	899.02	323.00
3	Tarlac	489.44	377.74
4-A	Quezon	1,131.13	350.80

Quantification of productivity and income gains from the MP Seeder technology package

Corn

On-farm trials of corn were established in 13 provinces (Ilocos Norte, Pangasinan, Cagayan, Tarlac, Camarines Sur, Albay, Sorsogon, Iloilo, Negros Occidental, Sultan Kudarat, South Cotabato, Batangas, Quezon).

Figure 15 compares the average grain yields from all sites where MP Seeder plots are higher than FP plots. Grain yield increased by 1.60t, 1.47t, 1.44t for hybrid corn (BtGr), white corn, and hybrid sweet corn, respectively. Higher crop establishment cost and crop care maintenance were observed in farmers' practice compared with MPS plots (Figure 16).

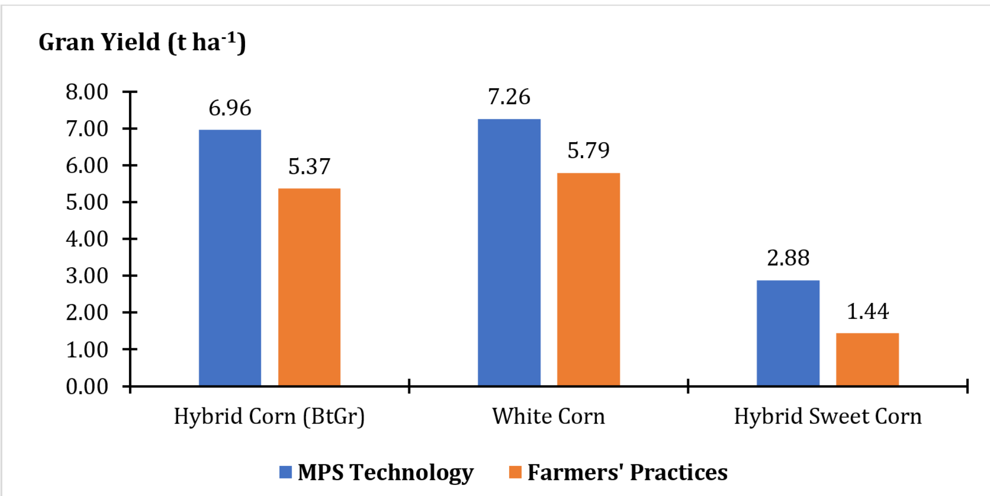

Figure 15. Grain yield of corn in MPS technology and farmers' practice.

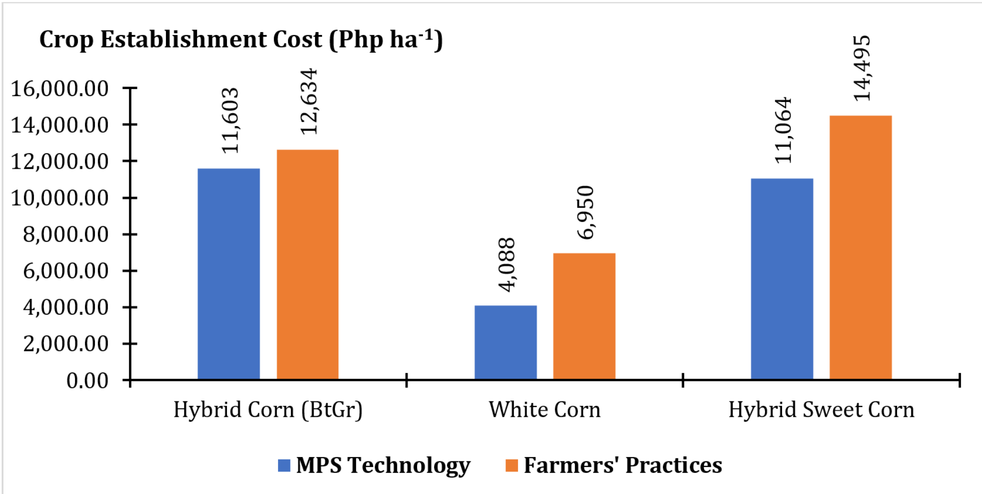

Figure 16. Crop establishment cost of corn in MPS technology and farmers' practice.

Across all sites, net income from MPS plots was consistently higher compared with farmers' plots (Figure 17) resulting from higher yield and lower production cost. Average net income was higher by Php 16,500 in hybrid corn (BtGr), Php16,800 in white corn, and Php 47,000 in hybrid sweet corn.

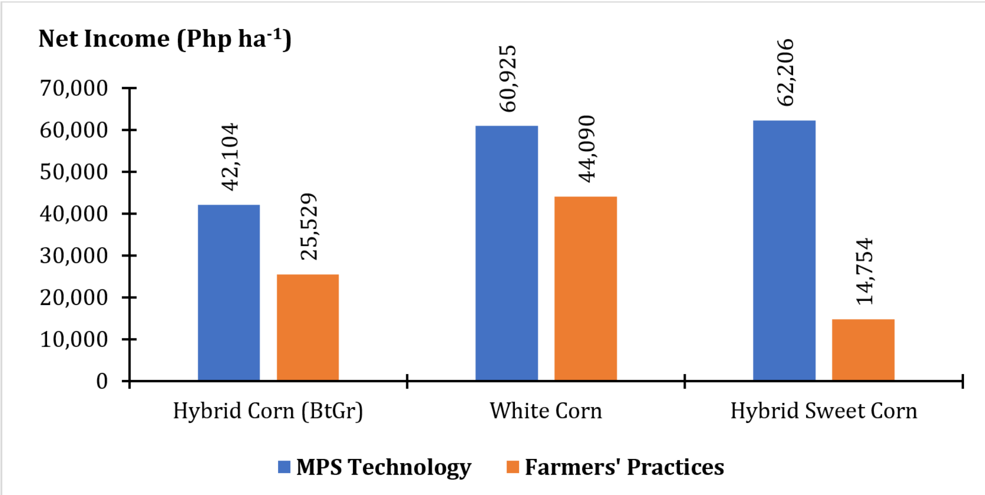

Figure 17. Net income of corn in MPS technology and farmers' practice

Mungbean

Grain yield of MPS plots for mungbean was 839.86 kg ha^{-1} , significantly higher than farmers' practice yield (350.51 kg ha^{-1}) (Figure 18). The same could be said of net income (Figure 19).

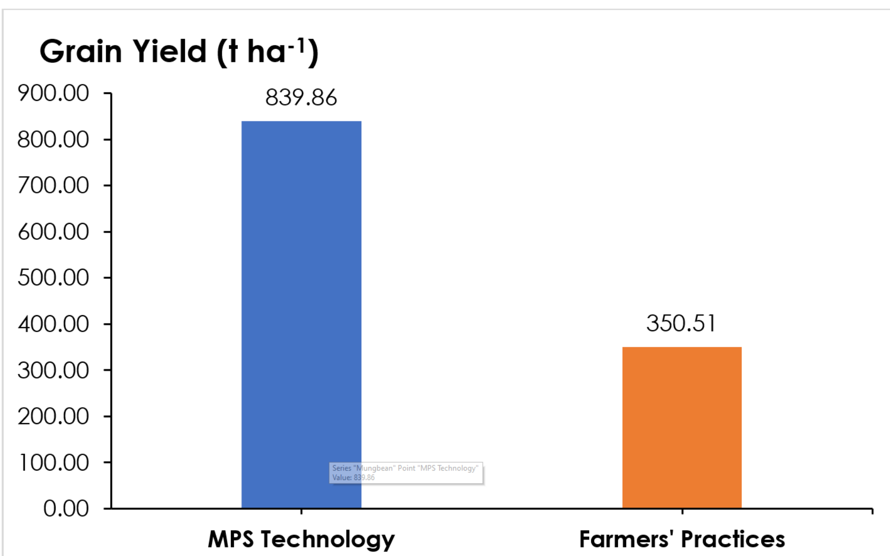

Figure 18. Grain yield of mungbean in MPS technology and farmers' practice.

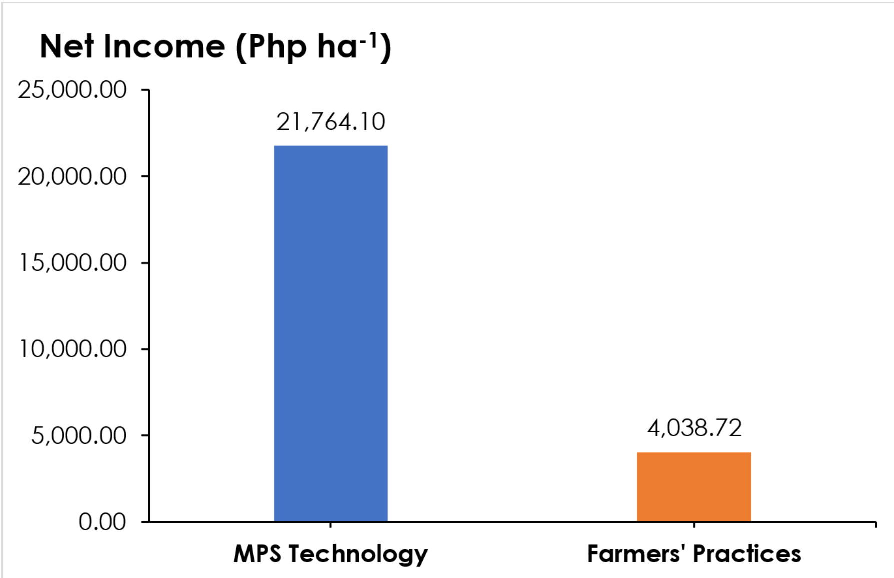

Figure 19. Net income of mungbean in MPS technology and farmers' practice.

Rice

On-farm trials for rice were established in six provinces (Ilocos Norte, Pangasinan, Camarines Sur, Sorsogon, Iloilo, and South Cotabato) to compare MP Seeder + BMPs with farmers' practices. Treatments were:

- MPS Technology – MP Seeder + Best management practice + Recommended variety at 60 kg/ha seeding rate
- Farmers' Practices – Farmers' crop establishment method + Farmers' management practice + Farmers' variety

Significantly higher average grain yield was attained from MPS technology (4.60t ha^{-1}) compared to 3.80t ha^{-1} from farmers' practice plots (Figure 20). Less crop establishment cost and higher yield spelled bigger net income by Php 12,000 ha^{-1} (Figure 21).

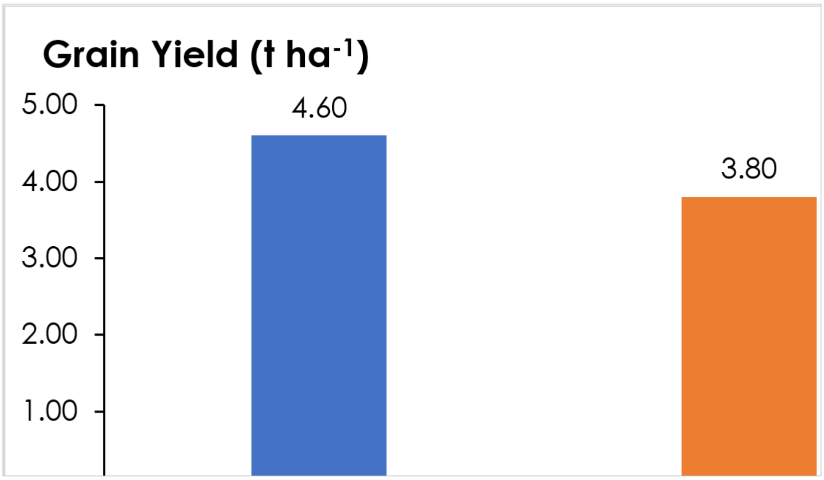

Figure 20. Grain yields of rice under two treatments.

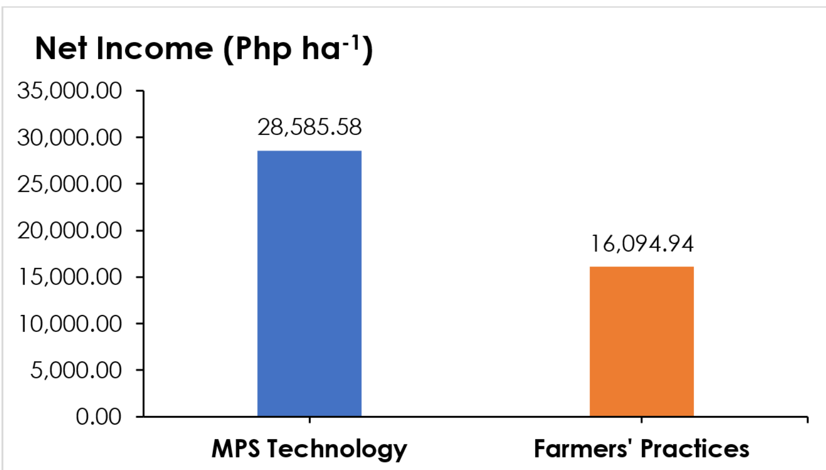

Figure 21. Net income of rice under two treatments.

Takeaways

- The amount of seeds and labor to establish rice under dry direct seeding is significantly lower in MP Seeder plots compared with Farmers' practices. Therefore, MP Seeder is a cost-reducing technology.
- Grain yields of rice, corn, and mungbean were significantly higher in MP Seeder plots compared with current farmers' practices.
- Total rice production cost was higher in Farmers' practice plots than in MP Seeder plots in rice, which led to higher net income and lower cost to produce a kilo of *palay*.
- Crop establishment cost for corn and mungbean was lower in MP Seeder plots compared with Farmers' practice plots.


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4

Development of MP Seeder plus for favorable and water-scarce rainfed lowlands (tail-end of irrigation) in the target regions

Elmer G. Bautista • Eugene L. Dingle • John Eric O. Abon • Eugenio P. Aquino • Aurora M. Corales

This chapter tackles the engineering component of the project, which is the development of MP Seeder plus. The key activities are the adjustment of MP Seeder plus options (fertilizer hopper and weeder) in rainfed and tail-end irrigated areas in the regions, development of options for optimum tillage, and capacity building for accredited local manufacturers. We discuss each of these activities in this chapter.

Enabling local manufacturers of agricultural machinery

Mechanization in rice and corn cultivation in the Philippines remains low. Only land preparation, threshing/shelling, and milling are classified as intermediate to high while the rest of the operations such as planting, transplanting, crop care, harvesting, and drying are low (PCAARRD, 2009).

Agricultural machinery and equipment are either manufactured locally or imported. Four-wheel tractors and engines are wholly imported; power tillers, pumps, transplanters, seeders, weeders, reapers, and postharvest equipment are locally manufactured (Amongo, 2011). About 400 machinery manufacturers exist all over the country: about 56% is in Luzon, 8% in Visayas and 36% in Mindanao (AMTEC, 2001). These include craftsmen and small-scale, seasonal manufacturers. Hand tractor remains the most widely accepted source of farm power in the country. Sales records from Agricultural Machinery Manufacturers and Distributors' Association (AMMDA) showed that from 2006 to January 2009, there were 3,159 two-wheel hand tractors sold. With the implementation of the Rice Competitiveness Enhancement Fund (RCEF) in 2019, the Philippine Center for Postharvest Development and Mechanization (PHilMech) has procured 20,076 units of various farm machines under the RCEF Mechanization Program in 2019-2021. Of the total units procured, 2,787 machines were hand tractors (Gomez, 2022).

Many farmers are still unaware of the available suitable machines that could help in farming operations. Local manufacturers play an important role in technology dissemination with the help of extension workers.

The manufacturers are among the key partners and beneficiaries of the project, which strategically selected them nationwide for fast and efficient technology dissemination and promotion. This also helps in reducing the additional cost of delivering the machines to customers. The success of developing commercial machines is in meeting the market demands within acceptable price levels, which could meet farmers' operational needs (PCAARRD, 2009).

The MP Seeder (Figure 1) has six accredited manufacturers: 4 in Luzon, 1 each in Visayas and Mindanao. There are three criteria followed in assessing if a manufacturer will be accredited to commercialize the machine: 1. Pass the Fairness Opinion Board assessment; 2. Their fabricated MP Seeder commercial unit underwent AMTEC Testing and Evaluation; and 3. Signed Technology Licensing Agreement with DA-PhilRice.

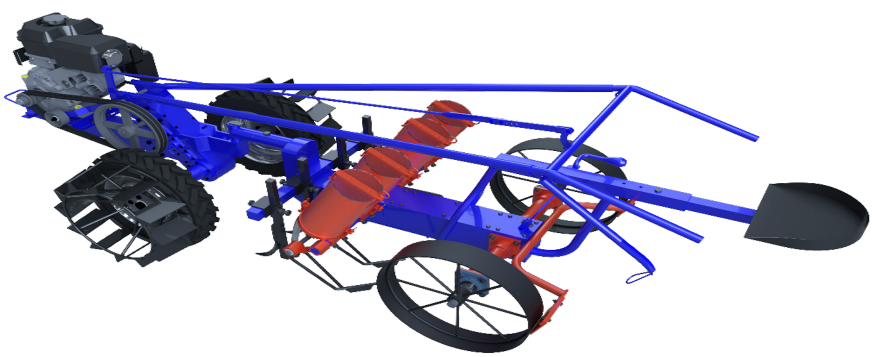


Figure 1. Isometric view of the MP Seeder.

The Agricultural Machinery Testing and Evaluation Center (AMTEC) is tasked to test, evaluate, and provide quality control services of agricultural machines as stipulated in Section 18 of the AFMECH Law.

To capacitate the local manufacturers, they were assisted during the AMTEC testing and evaluation of their fabricated commercial unit of MP Seeder. The 2019 to 2020 tests were based on the Philippine Agricultural Engineering Standards, PAES 123:2001 (Agricultural Machinery – Seeder and Planter – Methods of Test). The summary of results (Tables 1 to 6) show that MP Seeder has high theoretical field capacity minimum of 2.5 ha day^{-1} for rice, corn (3.5 ha day^{-1}), and mungbean (3.0 ha day^{-1}). However, due to frequent turning and limitations in the pivoting mechanism of the local handtractor at headlands, the average field efficiency is only 65% or an average actual field capacity of 1.95 ha day^{-1}.

According to the 2019 Reference Manual of Agricultural and Fisheries Machinery and Equipment, a precision seeder for rice should have minimum field efficiency of 60%, and 55% for corn seeder/planter and vegetable seeder. The seeding rates for rice, corn, and mungbean were 65, 20, and 27 kg ha^{-1}, respectively, which were higher by 10.5% than those indicated in the operator's manual but still within the acceptable range. Missing hills were also low for rice (1.2%), corn (13.5%), and mungbean (6.1%); average distances between hills were 144, 216, and 162 mm, in the same order.

Table 1. Summary of AMTEC test results for the Hontarciego Metal Craft commercial unit.

Performance Criteria	Rice	Corn	Mungbean
Actual Field Capacity, ha day^{-1}	1.34	2.4	1.89
Seed Delivery Rate, kg ha^{-1}	64.63	23.74	45.83
Field Efficiency, %	50.44	65.86	84.59
Uniformity of Work			
a. Row spacing, mm	206.7	585	200.9
b. Depth of seeding, mm	45.9	50.7	46.8
c. Distance between hills, mm	158.1	151.4	152.4
d. Number of seeds per hill	3.2	0.7	3.0
e. Missing hills, %	0	33	11.11
Number of operator/s	an operator and 2 persons guiding the operator and refilling the hoppers		

Table 2. Field performance test results for the Hontarciego Metal Craft commercial unit.

Particulars	Average		
Crop	**Rice**	**Corn**	**Mungbean**
Variety	ND	ND	ND
Weight of 1000 seeds, g	NM	331.05	65.96
Moisture content, % wb	14.34	12.85	14.34
Field area, m^2	662.5	680	672
Actual operating time, min	23.8	13.58	-17.1
Time lost owing to:			
a. Turning at headland, min	-	0.1	-
b. Adjustment, min	0	0	0
c. Repair, min	0	0	0
d. Refilling of seeds/fertilizers, min	NM	NM	NM
Actual working width, m	0.8	1.2	0.8
Traveling speed, kph	4.14	3.8	3.49
Effective field capacity, ha h^{-1}	0.167	0.190	0.236
Theoretical field capacity, ha h^{-1}	0.331	0.456	0.279
Field efficiency	50.44	65.86	84.59
Travel pattern	Headland pattern from backfurrow		
Fuel consumption, L ha^{-1}	4.377	3.088	2.455

Table 3. Summary of AMTEC test results for the VAL Agri Machineries commercial unit.

Performance Criteria	Rice	Corn	Mungbean
Actual Field Capacity, ha day^{-1}	1.472	1.91	2.2
Seed Delivery Rate, kg ha^{-1}	56.5	15.9	17.49
Field Efficiency, %	58.6	55.6	61.3
Uniformity of Work			
a. Row spacing, mm	202 ± 11.5	564 ± 63.2	600 ± 17.9
b. Depth of seeding, mm	35.5 ± 4.73	22.9 ± 4.08	15.0 ± 4.51
c. Distance between hill, mm	122 ± 24.2	264 ± 48.4	178 ± 43.5
d. Number of seeds per hill	3	1	2
e. Missing hills, %	3.49	7.50	0
Number of operator/s	Two (one operator and another refilling seeds and assisting the operator)		

Table 4. Field performance test results for the VAL Agri Machineries commercial unit.

Particulars		**Average**	
Crop	Rice	Corn	Mungbean
Variety	NSIC Rc 416	NK Syngenta	ND
Weight of 1000 seeds, g	28.1	293	75.8
Moisture content, % wb	12.7	10.6	11.4
Field area, m^2	1000	1058	1058
Actual operating time, min	32.5	25	23.1
Time lost owing to:			
a. Turning at headland, min	-	-	-
b. Adjustment, min	-	-	-
c. Repair, min	0	0	0
d. Refilling of seeds/fertilizers, min	0	1.72	0
Actual working width, m	0.8	1.2	0.8
Traveling speed, kph	3.94	3.58	3.75
Effective field capacity, ha h^{-1}	0.184	.239	0.275
Theoretical field capacity, ha h^{-1}	0.315	0.430	0.449
Field efficiency	58.6	55.6	61.3
Travel pattern		Headland pattern from back furrow	
Fuel consumption, L ha^{-1}	2.63	2.66	2.03

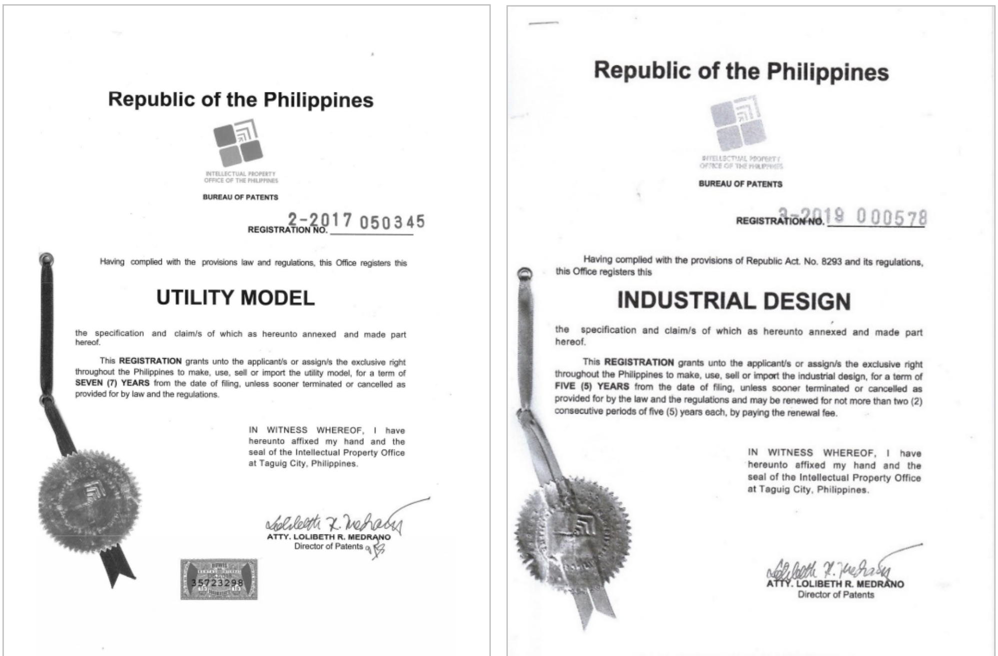
Table 5. Summary of AMTEC test results for the New Era Industries commercial unit.

Performance Criteria	Rice	Corn	Mungbean
Actual Field Capacity, ha day^{-1}	1.736	2.38	2.01
Seed Delivery Rate, kg ha^{-1}	74.25	20.9	17.5
Field Efficiency, %	74.2	69.7	60.9
Uniformity of Work			
a. Row spacing, mm	202 ± 8.0	580 ± 17.9	587 ± 20.9
b. Depth of seeding, mm	41.4 ± 6.44	44.3 ± 4.50	45.8 ± 7.14
c. Distance between hills, mm	152 ± 30.5	232 ± 76.5	156 ± 59.9
d. Number of seeds per hill	3 ± 1	1	1
e. Missing hills, %	0	0	7.20
Number of operator/s	Two (one operator and another refilling seeds and assisting the operator)		

Table 6. Field performance test results for the New Era Industries commercial unit.

Particulars	Average		
Crop	**Rice**	**Corn**	**Mungbean**
Variety	NSIC Rc 420	IES Glut #7	ND
Weight of 1000 seeds, g	24.3	282.2	69.0
Moisture content, % wb	10.7	12.6	10.8
Field area, m^2	1000	1003	1058
Actual operating time, min	27.7	20.2	25.3
Time lost owing to:			
a. Turning at headland, min	6.60	5.50	8.4
b. Adjustment, min	-	-	-
c. Repair, min	0	0	0
d. Refilling of seeds/fertilizers, min	3.72	0	0
Actual working width, m	0.8	1.2	0.8
Traveling speed, kph	3.65	3.56	3.44
Effective field capacity, ha h^{-1}	0.217	.298	0.251
Theoretical field capacity, ha h^{-1}	0.292	0.428	0.412
Field efficiency	74.2	69.7	60.9
Travel pattern		Headland pattern	
Fuel consumption, L ha^{-1}	2.53	2.54	1.39

The DA-PhilRice is granted exclusive rights to the MP Seeder with an IP registered as Utility Model (PH-2-2017-050345) and Industrial Design (PH-3-2019-000578) until May 30, 2024 and may be renewed for not more than two (2) consecutive periods of five (5) years each. Pursuant to the Implementing Rules and Regulations of Republic Act 10055 or the Technology Transfer Act of 2009, DA-PhilRice requested a Fairness Opinion Report (FOR) for each local manufacturer from the Fairness Opinion Board (FOB) of the Department of Science and Technology. The FOR is an assessment of whether the proposed technology transfer agreement between DA-PhilRice and the technology adopter (local manufacturers) is fair to the government. It was a prerequisite for the commercialization of the MP Seeder technology, which is a publicly funded research. After the favorable FOR was released, the Technology Licensing Agreement was signed in 2021.



a. Utility Model b. Industrial Design

Figure 2. IP of the MP Seeder Industrial Design.

Table 7 shows the status and remarks of manufacturers on each criterion for commercialization. As of October 2022, five manufacturers have completed all the requirements.

Table 7. Manufacturers for the mass production of the MP Seeder.

Region	Manufacturer	Passed Fairness Opinion Report	AMTEC tested	Signed Technology Licensing Agreement
1	New Era Industries	yes	yes	yes
2	ACT Machineries and Metal Craft Corporation	yes	yes	yes
3	VAL Agri Machineries and Machine Shop	yes	yes	yes
4A	Globall Marketing and Construction Corp.	yes	yes	yes
6	Hontarciego Metal Craft	no	yes	no
12	Green Valley Machineries	yes	yes	yes

Design improvement of the Multi-Purpose Seeder

Calibration and testing of the MP Seeder for seed delivery

The hoppers for corn were modified to reduce the incidence of missing hills caused by the clogging of seeds on the holes of the metering plate. Laboratory calibration gathered initial data and actual field calibration was performed during crop establishment in Bicol and in Batangas and Quezon.

Rice calibration

Table 8 shows the seeding rates and 1000 grain weights during the laboratory tests using actual samples of rice varieties planted. When the standard metering plate for rice with 8 holes at 12.5 mm diameter was used, seeding rates varied between 77 kg ha^{-1} (Rc 222) and 82 kg ha^{-1} (Rc 480). The average rates obtained were higher by 17.5 kg than the recommended 60 kg ha^{-1}.

Table 8. Seeding rates of four rice varieties using standard 8-hole plate during laboratory testing.

Variety	Seeding rate (kg ha^{-1})	1000 grain weight (g)	Computed plant population
Rc 480	82	19	4,316
Rc 416	78	23	3,391
Rc 420	73	25	2,920
Rc 222	77	26	2,961

Note: Each entry is an average of four replicates.

Field calibration was done before crop establishment using NSIC Rc 480 in Region 5 (July 2020). Although the actual values in Table 9 are lower than the laboratory test values in Table 8, they were still greater than the recommended rate. There is a need to adapt the seeder to a particular region by reducing the hole diameter of the metering plate from 12.5 mm to 11.0 mm consequently pulling down the seeding rate to hit the target.

Table 9. Seeding rates using standard 8-hole plate during field calibration prior to crop establishment.

Site on Region 5	Rice variety	Seeding rate (kg ha^{-1})
Oas, Albay	NSIC Rc 480	72
Penafrancia, Sorsogon City	NSIC Rc 480	69

Note: Each entry is an average of four replicates.

To satisfy the recommended seeding rates, different plates were fabricated for thorough calibration. Several plates were calibrated with a hole diameter of 12.5 mm with varying numbers of holes to achieve the seeding rates 40, 60, and 120 kg ha^{-1}. Below are results of the laboratory tests for three rice varieties: a 5-hole plate should be used for 40 kg ha^{-1} seeding rate; 7-hole plate for 60 kg ha^{-1}, and 12-hole plate for the 120 kg ha^{-1} .

Table 10. Seeding rates (kg ha^{-1}) of different metering plates used in the MP Seeder during laboratory calibration.

Variety	5-hole plate	7-hole plate	8-hole plate	10-hole plate	12- hole plate
NSIC Rc 420	39	55	77	107	120
NSIC Rc 222	37	68	72	92	132
NSIC Rc 416	38	67	71	96	115

Note: Each entry is an average of four replicates.

Corn calibration

The hoppers for corn were improved by repositioning the seed scraper of the seed control plate from 180° to 90° closer to the discharge hole. The spring-type ejector preventing the clogging of corn seeds during seeding was also re-oriented and aligned for its effectiveness during operation. During laboratory calibration, the wheels were manually turned 10 times to dispense 70 seeds per hopper or a total of 140 seeds for both hoppers. The test resulted in an increasing number of seeds dispensed when the seed plate clearance is also increased as shown in Table 11. Clearance greater than the recommended 0.5 mm accommodated more corn seeds, as two or more seeds of relatively smaller size can occupy one hole, thus increasing the seeding rate.

Table 11. Increasing seed plate clearance dispenses more corn seeds.

Conditions	Hopper #1	Hopper #4	Total seeds dispensed
	Seeds dispensed	Seeds dispensed	
Hopper 3/4 full, (seed plate clearance of 0.5 mm)	77	75	152
Hopper 3/4 full, (clearance of 0.75 mm)	80	76	156
Hopper 3/4 full, (clearance of 1.0 mm)	86	79	165
Hopper 3/4 full, (clearance of 1.7 mm)	88	79	167

Note: Each entry is an average of four replicates.

In December 2020, corn crops were established in Lipa (LARES) and Quezon (QARES) Agricultural Research Stations. The seeding rates are shown in Table 12 where those of Lagkitan variety were below 18 kg ha^{-1} while those of Hybrid NK6410 BtGr were higher.

Table 12. Seeding rates of two corn varieties.

SITE	Variety	Seeding rate (kg ha^{-1})		Computed actual plant population (ha^{-1})
		Field test	Actual test	
LARES	Lagkitan IPB UPLB	16.2	15.3	60,236
	Lagkitan IPB UPLB		17.3	68,110
QARES	NK6410BtGr	23.6	18.8	80,935
	NK6410BtGr		22.5	67,625

Note: Actual seed weight of Lagkitan IPB UPLB = 0.254 g/seed; of Hybrid NK6410 BtGr = 0.278 g/seed

Mungbean calibration

Mungbean crops (Table 13) were established in the same research stations as corn. Sown by the seeder using the standard 8 holes at 9.5-mm-diameter metering plate were 3 to 5 seeds per drop resulting in an actual seeding rate of 25.5 kg ha^{-1}, higher than the target of 20 kg ha^{-1}. This led to the fabrication of a modified metering plate for mungbean by drilling the holes with 7.5-mm diameter on top and counter boring with 9.5-mm diameter at the bottom. This resulted in 3 seeds per drop and a seeding rate of 10.3 kg ha^{-1}. On the other hand, the fertilizer dispensed in QARES was 4 kg less than the target of 200 kg ha^{-1} of complete fertilizer.

Table 13. Seeding and fertilizer rates during mungbean establishment in two sites.

Site	Seed plate Description	Seeding rate (kg ha^{-1})		Computed actual plant population (ha^{-1})	Fertilizer rate (kg ha^{-1})	
		Field test	Actual test		Field test	Actual test
LARES	Standard	25.5	27.6	511,111	172	131.5
QARES	Modified	10.3	12.0	222,222	178	195.72

Note: 1. Each entry is an average of four replicates.
2. Actual seed weight of Mungbean Pag-asa 7 = 0.054 g/seed

Modification of seed ejector for corn seeding

Seeding of corn in the previous seasons had been problematic due to the high percentage of missing hills caused by the clogging of seeds on the seed plate, resulting from the various sizes of the seeds. The entry of 2 to 3 small seeds in a single hole of the seed metering plate would cause clogging, and all seven holes could clog simultaneously. Putting the spring ejector lessened missing hills, but in the long term it could damage the metering plates due to frequent scratching. The continuous sliding of the spring-loaded metal to the plate usually creates a dent that eventually damages the plate.

A new option was placing a miniature bearing loaded with a spring (Figure 3). The ejector was positioned at the discharge hole, which would react when the hole aligned with it. This would eject seeds without damaging the seed plate because the rotating device protects it against compression. A laboratory test then ascertained the effectiveness of the ejector. Seed hoppers were loaded ¼ full while the MP Seeder was jacked up and the ground wheel was rotated 10 times. Seeds delivered were collected and counted. Expected to be dispensed were 70 corn seeds on the assumption that a single seed was dropped per metering hole. Two hoppers (1 and 4) delivered 71 and 75 seeds (Table 14), respectively. This means extra seeds were delivered and missing hills were highly unlikely to happen.

Table 14. Number of seeds dispensed per seed hopper.

Hopper position	Number of seeds dispensed
Hopper 1	71
Hopper 4	75

Note: Number of seeds dispensed was an average of four replicates.

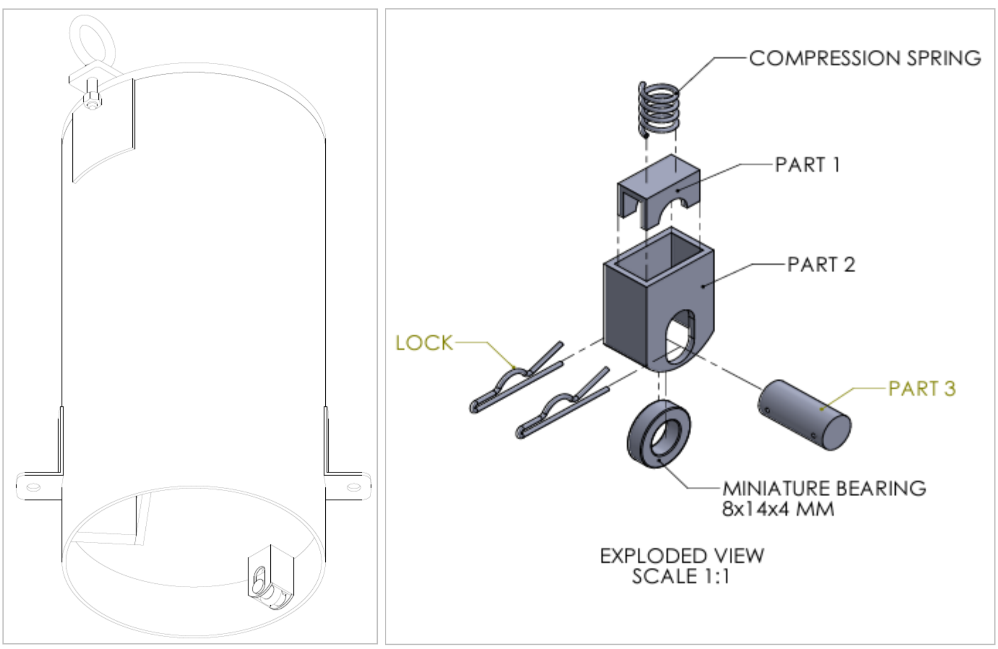


Figure 3. Seed ejector using miniature bearing loaded with spring.

Development of fertilizer applicator for MP Seeder plus options

Simultaneous application of basal fertilizer during seeding is widely practiced in the country. The target fertilizer rates for OPV and hybrid corn were 350 and 465 kg ha^{-1} of complete fertilizer, respectively. The need to dispense approximately 5 and 6.4 grams of complete fertilizer, respectively, for OPV and hybrid corn resulted in a 7-slotted plate design with 8 mm and 10 mm thickness (Table 15). The fabricated plates dispensed the desired 5.2 and 6.6 grams per slot (Figure 4). The design of the hopper base plate discharge hole was also modified to match the current size of the fertilizer metering plate. The seed control plate, which was previously designed for 5mm-thick metering plate, was also adjusted due to the varying thickness of the fertilizer plate up to 10 mm.

Table 15. Summary of fertilizer discharge using three plate thickness.

Plate thickness (mm)	Amount dispensed (g per hole)	Actual fertilizer rate (kg ha^{-1})
8.5	5.2	380
10	6.6	481
11.5	8.8	642

Figure 4. Slotted 10-mm-thick fertilizer plate for corn to dispense 465 kg/ha of complete fertilizer.

To further improve fertilizer hopper performance, a movable restrictor plate was added to the discharge hole to regulate the final delivery of fertilizer (Figure 5). Covering the discharge hole by 2%, 4%, 6%, and so on will reduce correspondingly the amount of fertilizer being metered out by the machine preventing over delivery.

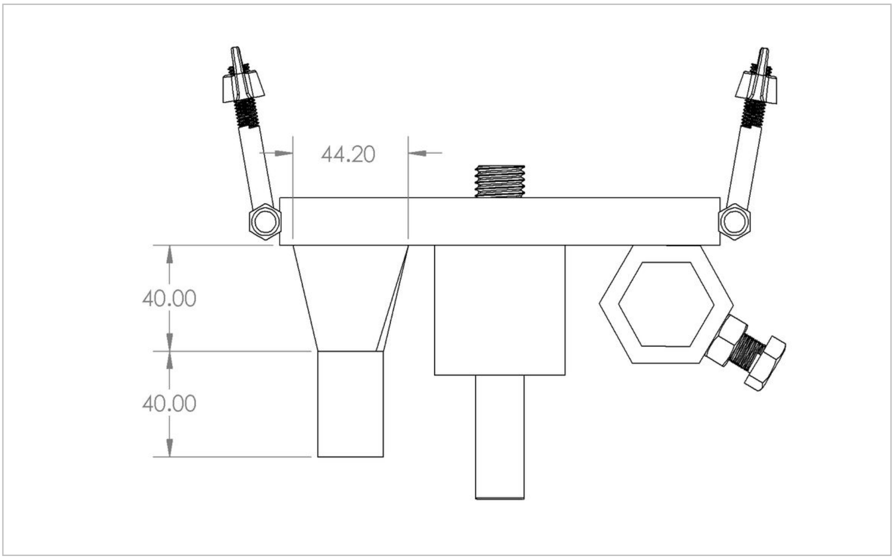


Figure 5. Improved fertilizer hopper.

Figure 6 shows the incremental setting in millimeters of the restrictor plate covering part of the exit hole where fertilizer is being dispensed. This setup was used during the calibration test to monitor visually if fertilizer would clog, which did not occur.

Figure 6. Improvised restrictor plate setting during testing.

The restrictor plate as an additional option further improved the machine's required fertilizer delivery rate for hybrid and OPV corn, and mungbean. The incremental increase of the restrictor mechanism is inversely proportional to the rate of fertilizer being dispensed by the machine in all cases.

To achieve the recommended delivery rate for hybrid corn, the restrictor plate must be set to 9 mm, narrowing the discharge hole. Other values of delivery rates can be achieved by interpolation or extrapolation technique whichever is applicable.

Mechanization option for dry direct-seeding

Mechanized crop establishment and evolved weed resistance to herbicide had been a great challenge in the sustainability of dry direct-seeding. In rainfed lowlands where water management is poor, weed problems are more severe with direct-seeding than with transplanting. Broadcasting, as commonly practiced in these areas, results in weed control problems, whereas regular row planting is advantageous for manual and mechanical weed control (Sipaseuth et al., 2001).

A mechanical weeder for dry direct-seeding has been developed to address both weed resistance to herbicide and laborious and expensive manual weeding. The 4-row weeder has already undergone several functionality tests on top of field tests (Fig. 7a) without standing crops both in wet and dry field conditions. With an initial capacity of 1.5 ha day^{-1}, the weeder was fine-tuned (Figure 7b) to address the erratic forward speed, proper gear combination for the ground wheel and weeding rotors, and aesthetics.

Figure 7. Mechanical weeder subjected to a.) field test and b.) fine-tuning.

After the modifications based on results of previous tests, the final prototype of the weeder (Figure 8) was fabricated and initially tested on a wet field. It performed well covering four rows with a rotor width of 9 cm. It has a capacity of 1.5 ha day^{-1} with an estimated weeding efficiency of 70%. Data will be further verified through a series of field tests including other performance data (e.g., percent plant damaged, field efficiency, wheel slippage, and fuel consumption).

Figure 8. Final prototype of the 4-row mechanical weeder.

The 4-row mechanical weeder was also registered as Industrial Design with the Intellectual Property Office of the Philippines (IPOPHIL) with Registration No. PH-3-2020-050677.

Digitally Signed by IPOPhil
10/06/2022
Atty. LOLIBETH R. MEDRANO

CERTIFICATE OF REGISTRATION
INDUSTRIAL DESIGN

REGISTRATION NO. 3/2020/050677

Having complied with the provisions of Republic Act No. 8293 and its regulations, this Office certifies that this Registration with the following particulars was registered on **28 January 2022** with a term until **23 November 2025**, unless otherwise earlier cancelled, and may be renewed for not more than two (2) consecutive periods of five (5) years each, by paying the renewal fee.

This registration grants the registrant the right to restrain, prohibit any unauthorized person or entity from making, using, offering for sale, selling or importing the industrial design.

Registrant:
Philippine Rice Research Institute (PRRI) [Science City of Muñoz, Nueva Ecija, PH]

Title of the Industrial Design:
WEEDER

Designers:
ABON, John Eric O. [Science City of Muñoz, Nueva Ecija, PH]; BAUTISTA, Elmer G. [Science City of Muñoz, Nueva Ecija, PH] and DINGLE, Eugene L. [Science City of Muñoz, Nueva Ecija, PH]

Publication Date:
28 January 2022

Atty. LOLIBETH R. MEDRANO
Director of Patents

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Bureau of Patents

Figure 9. Registered IP of 4-row mechanical weeder.

Capacity-building of accredited local manufacturers

In support of local manufacturers of the MP Seeder, their fabricated units were procured that served as demonstration units during technology demonstration in target areas. The units were also assessed based on standard specifications set on the detailed design of the machine. Components that failed to meet the specifications were refabricated until the quality was approved. In total, the project has procured 27 units of MP Seeder (Table 16) across seven regions with the highest in Regions 1, 3, and 12.

Table 16. List of available units of MP Seeder and handtractor per region.

Region	Total Units		In-Charge	
	MP Seeder	Handtractor	MP Seeder	Handtractor
1	7	1	PhilRice Batac	PhilRice Batac
2	2	-	CSU Lal-lo (1), ACT Machineries and Metal Craft Corporation (1)	-
3	6	6	PhilRice CES	PhilRice CES
4A	1	1	UPLB	UPLB
5	1	1	PhilRice Bicol	PhilRice Bicol
6	3	-	PhilRice Negros (1), Hontarciego Metal Craft (2)	-
12	7	3	Green Valley Machineries	PhilRice Midsayap (1), Green Valley Machineries (2)
Total	**27**	**12**		

To ensure that MP Seeder units manufactured are of good quality, a template (Table 17) was developed for quality control during inspection. Failure to meet every specification requires refabrication of the inferior components.

Table 17. Checklist for MP Seeder Inspection and Calibration

Checklist for MP Seeder Inspection and Calibration.			
MP Seeder parts	**Passed**	**Failed**	**Remarks**
	✓	✖	
Hitch Point			
Size (44mm dia)			
Length (300mm) at 60mm dia.			
movable up to 45˚ and removable			
Hoppers			
4 sets PVC pipe, 6"			
Bolt and Nut (M8 or M10)			
Seed Divider orientation (facing right when in back)			
Hopper cover (steel plate or plastic)			
Spring ejector			
Metering plates and Base plates			
4 sets for Rice 8 holes (1/2 " dia, 5mm thk)			
2 sets for Corn 7 holes (1/2" dia, 5mm thk)			
2 sets for mungbean 8 holes (3/8" dia, 5mm)			
2 sets fertilizer plates (open slotted, 10mm			
Clearance to metering plate to base plate (0.5mm)			
Seed discharge holes adjusted to design of fertilizer plate			
Bevel gear and drive shaft			
8 sets of bevel gear (90˚ orientation)			
2 set screw in place			
Proper tightness of set crew			
Flange bearing, UCF204 and lock end			
Bevel gear orientation (facing right when in front)			
No clearance bet. Bevel gear and base plate bearing			
Sprocket properly screwed (12T, Rc60)			
Clutch Component			
Easily engage and disengage			
Minimum 15mm round bar			
Spring Loaded on handle			
Grease for lubrication			
Bearing, (6008 or 6208)			
Sprocket, Rc60 12T			
Ground Wheel			
Shaft size (32mm)			
Flange bearing, UCF206			
No clearance from ground wheel to flange bearing			
Bolt and nut end lock on shafting			
Ground wheel diameter (500mm, 5mm thk)			
Furrower and Furrow Holder			
Proper positioning of furrow holder			
Furrow opener side and bottom enclosure (3mm plate)			
Hose guide 25mm dia			
Chemical transparent hose 25mm dia			
Size of bolt and nut, min. M14			
Square bar, 25mm			
At least 2" clearance between ground and seed discharge point			
Furrow closer bottom stopper			

Inspection no. ____________

Manufacturer: ______________________________ **Date:** ____________________

Site address: ____

Inspector (s): ______________________________ **Signature:** ____________________

______________________________ **Signature:** ____________________

______________________________ **Signature:** ____________________

The Multi-Purpose Seeder Operational Guide Book

Developed to help end-users in proper field preparation requirements, its operation, maintenance, and troubleshooting as well as its benefits, the guide book also serves as a promotional material and a requirement when filing for AMTEC testing and evaluation. The final copy of the operational guide book for rice, corn, and mungbean (Figure 10) has the following ISBN numbers: 978-621-2022-57-7 and 978-621-8022-58-4 (pdf). Each unit of MP Seeder to be sold will come with the guide book as agreed during the fabricator's technical briefing. The guide book has also been translated into three (3) languages (e. g., *Pilipino*, *Iloko*, and *Hiligaynon*) for wider promotion and adoption. The *"Gabay sa Tamang Paggamit ng Multi-Purpose Seeder para sa Palay, Mais, at Munggo"* (Figure 11.a) has the following ISBN numbers: 978-621-8022-93-5 and 978-621-8022-94-2 (pdf). The *Iloko* translation *"Bayabay iti Panagusar iti Multi-Purpose Seeder para ti Pagay, Mais, ken Balatong"* (Figure 11.b) has the following ISBN numbers: 978-621-8022-91-1 and 978-621-8022-92-8 (pdf). The *Hiligaynon* translation *"Talamdan sa Paggamit sang Multi-Purpose Seeder para sa Humay, Mais, kag Munggo"* (Figure 11.c) has the following 978-621-8022-95-9 and 978-621-8022-96-6 (pdf).

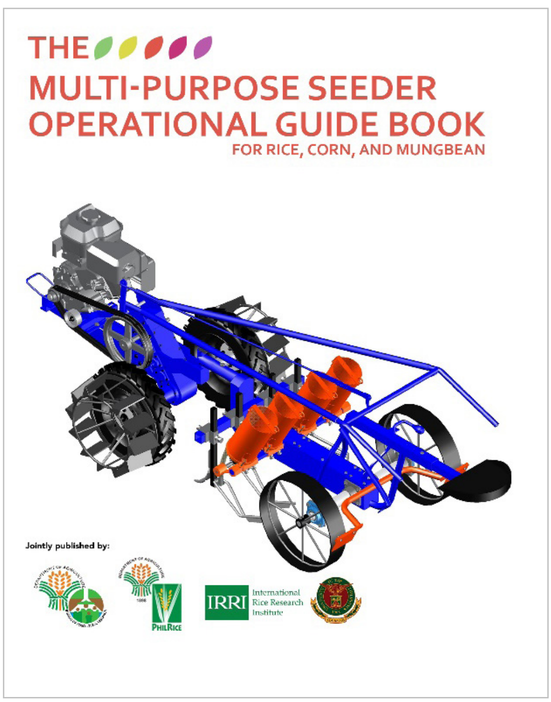

Figure 10. Front page of MP Seeder operational guidebook.

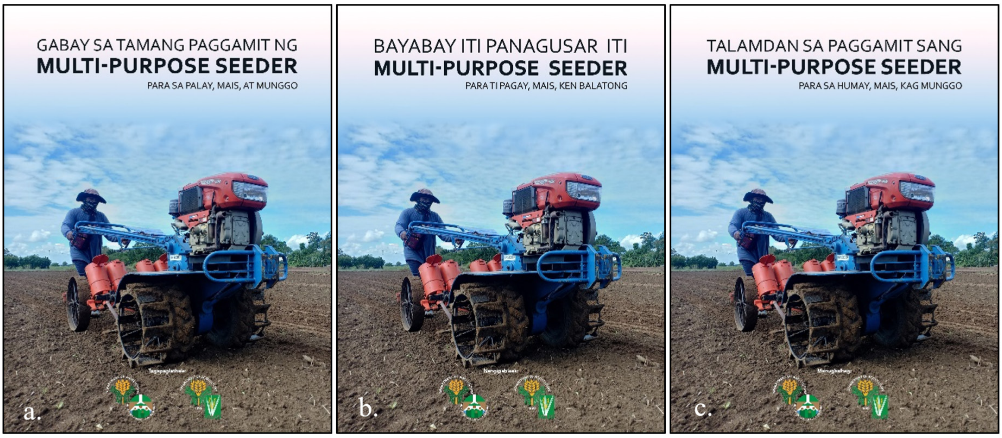

Figure 11. Translations of the MP Seeder Operational Guide Book in (a) *Pilipino*, (b) *Iloko*, and (c) *Hiligaynon*

Takeaways

- Mechanized dry direct seeding using the MP Seeder could potentially level up the mechanization of local major crops produced.

- With the licensed local manufacturers, the promotion of dry direct seeding technology using the MP Seeder will be intensified. The manufacturers have been duly capacitated to commercialize the machine.

- All MP Seeder units produced by local manufacturers will undergo quality control. Each unit sold would also come with an operational guide book and the developed best management practices for the technology.

- The MP Seeder being a risk-reducing technology with low acquisition cost could increase its acceptability among farmers.

- The MP Seeder is well-calibrated for its delivery of seeds for rice, corn, and mungbean with an option of simultaneous application of fertilizer in corn and mungbean.

- The developed 4-row mechanical weeder has good potential as a mechanization option for dry direct-seeding. It could be used in moist fields with crops planted in rows with heights not higher than 15 cm.

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5

Development of pathways for uptake of the Modified Dry Direct Seeding (MDDS) technology

Aurora M. Corales • Glyza M. De Gracia • Eugene L. Dingle • Elmer G. Bautista • Royette C. Santos

This chapter details the process in identifying and engaging project stakeholders, conduct of Focus Group Discussions to determine the opportunities and challenges in the adoption of direct seeding, capacity-building programs, and promotion and dissemination activities to reach out to more farmers.

A. Stakeholder engagement and identification of opportunities and challenges in direct seeding

A.1. Inception meeting for stakeholder engagement

Key persons from each target province were invited to two inception meetings. The activities (1) discussed the protocol with partners in the project sites; (2) reviewed the duties and responsibilities of partners; (3) selected project sites per province in consultation with partners; (4) discussed project deliverables and timeline of activities; and (5) discussed budget-sharing scheme among partner agencies.

The first meeting was participated in by 42 key persons (23 men, 19 ladies) from Regions 5, 6, and 12 (Figure 1) held at DA-PhilRice in Nueva Ecija on April 30, 2019; that for Regions 1, 2, 3, and CAR was joined by 43 individuals (27 men,16 ladies), held in Baguio City on May 10, 2019 (Figure 2).

Figure 1. The first inception meeting.

Figure 2. The second inception meeting.

During the inception meetings, potential partner-agencies were given time to present the profile of their respective areas of coverage: rice area according to ecosystem, source of irrigation, location of drought-prone areas, cropping pattern, method of crop establishment, and yield performance. Most of the constraints identified related to direct seeding are weeds, limited water supply, change in rainfall pattern, and low farm productivity. An action plan to address these constraints and challenges was formulated by the groups that includes technology validation trials to demonstrate at farmers' fields the new machine for direct seeding.

A.2 Project briefing cum consultation meeting with community partners

Project briefings introduced the project to partners and collaborators. Farmer-cooperators were selected and technology verification sites validated based on set criteria (visibility, accessibility, and interest of farmers to test the technology). The detailed experimental layout, protocol, research supplies and materials needed, data to be collected for on-farm generation and verification trials were thoroughly discussed during the briefings. Some 150 partners participated in the briefings conducted by the project team across the country as shown in Figure 3.

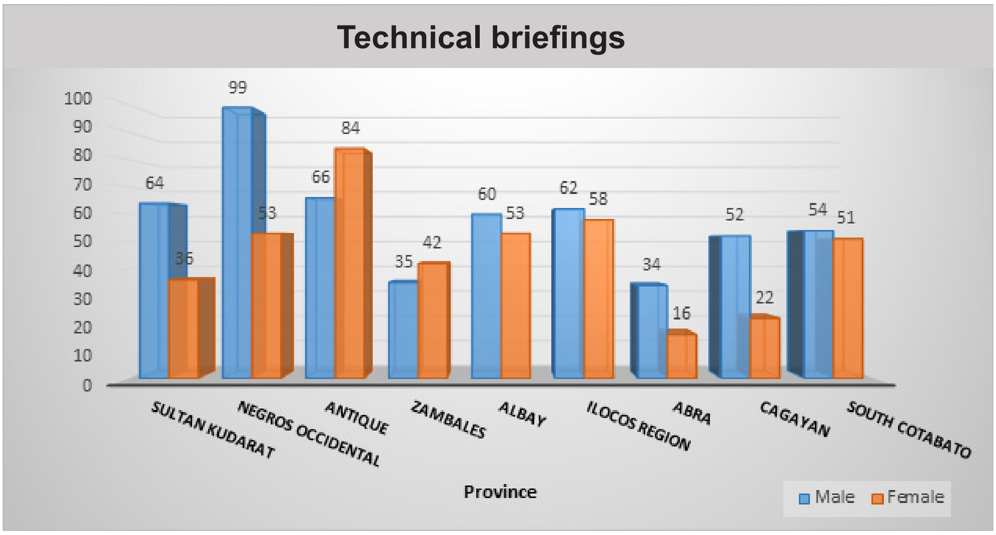

Figure 3. Number of participants in technical briefings.

B. Raising awareness on MP Seeder technology

B.1 Technology verification trials and field days

Field days (Figure 4) were conducted to showcase the MP Seeder package (MP Seeder machine + drought-tolerant variety + Best Management practice) trials to Regions 1, 2, 3, 5, 6, 12, and CAR. Field tour, MP Seeder technology demonstration, and open forum were highlights of the activity. Most frequently asked questions were the following: (a) How to avail of the MP Seeder? Can we avail of the unit through RCEF?; (b) How much is the machine?; (c) What is the seeding rate to be used?; (d) How to be a cooperator?; (e) Can this be used in sloping land areas?; (f) Can we still reduce the weight of the machine?; and (g) Can we still reduce the seeding rate?

Feedback on the use of MP Seeder were: (a) the machine is convenient to use; (b) requires less labor and seeds; (c) results show good crop stand; and (d) comparable to transplanting operation. Suggestions were also raised such as: (a) use of non-corrosive materials when the machine is ready for commercialization; (b) engrave a marker in centimeters in between rows and furrow depth; (c) use of lighter materials to facilitate operation and transportation of the machine; (d) provision of idler stopper for the hand tractor; and (e) improve the machine to minimize missing hills.

Around 1,000 participants benefited from the awareness campaign to introduce the MP Seeder package to targeted end-users. Based on survey conducted, an average Customer Satisfaction Rating (CSR) of 2.89% was achieved during these activities which is equivalent to "excellent" in the metrics developed for such activity.

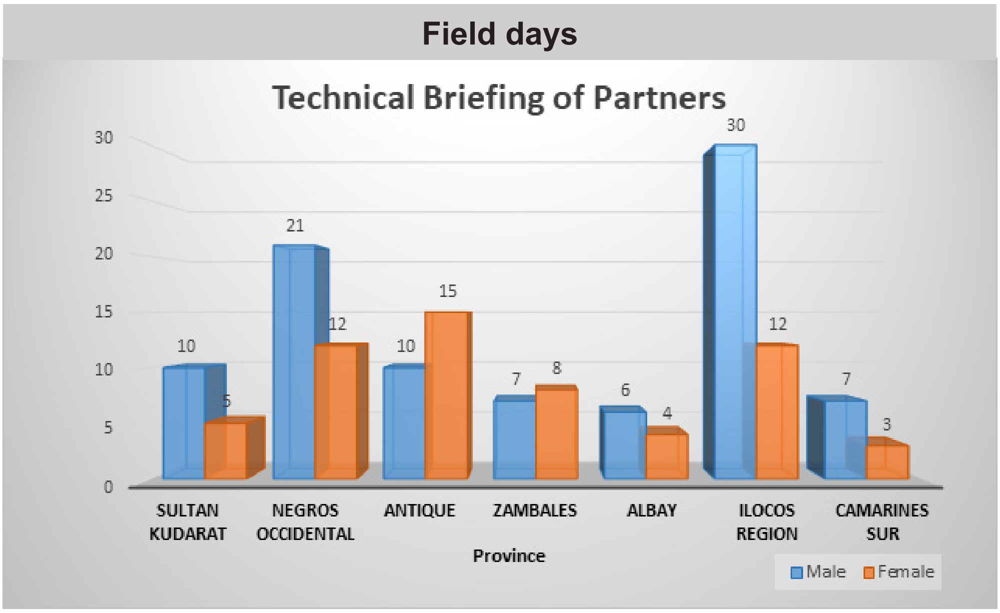

Figure 4. Summary of Farmers' Field Days conducted in different provinces.

Figure 5a. Farmers' Field Days.

Figure 5b. Farmers' Field Days.

B.2 Raising awareness through field walks

To focus farmers' attention on the potential of MP Seeder in reducing costs in crop establishment, field walks and forums were conducted in Nueva Era, Ilocos Norte participated in by 40 farmers (32 men) on October 9, 2020 and in Umingan, Pangasinan with 50 participants (26 men, 24 ladies) on March 5, 2021 (Figures 5a and 5b). The activity was composed of a) field tour along the rice and mungbean trials established with the use of MP Seeder; b) actual demonstration of the farm equipment; and c) Farmers' Forum to answer queries regarding the machine. Farmer-cooperators in the community shared their MP Seeder experience such as ease in crop establishment, better weed management, and the savings in labor costs. The activity garnered "Excellent" customer satisfaction rating.

B.3 National Forum to launch Mechanized Dry Direct Seeding Technology

The webinar titled *"National Forum on MP Seeder: An Innovative Approach in Improving Productivity using Mechanized Dry Direct Seeding Technology"* conducted on June 21, 2021 via ZOOM was attended by 188 participants from different sectors. These included institutions and organizations such as the UP Los Baños, PhilRice, DA-Bureaus of Agricultural Research/ Fisheries Engineering, DA-Agricultural Training Institute, all Regional Field Offices specifically Rice, Corn, and R&D Coordinators, PHilMech, state universities, research centers/stations, manufacturers, local government units in Regions 1, 2, 3, 4A, 5, 6, 12, and CAR. Figure 6 sketches the percentage of zoom participants per region. The webinar was also livestreamed at DA-PhilRice Facebook page with about 3,000 views nationwide.

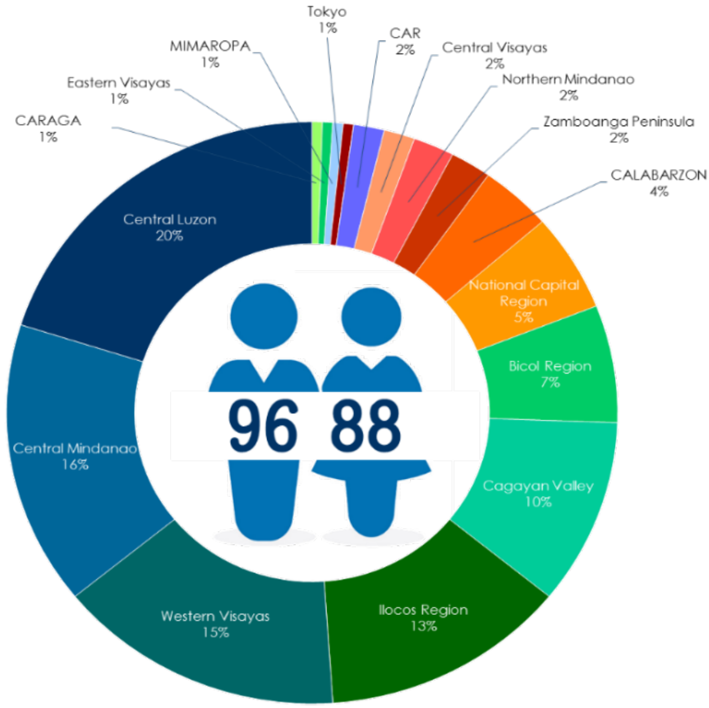

Figure 6. Percentage of zoom participants per region.

Presented during the National Forum (Figure 7) were: (1) The MP Seeder to showcase its potentials; (2) Best Management Practices in Rice Production using the MP Seeder; (3) Best Management Practices in Corn and Mungbean Production; and (4) Reaching Out to Farmers in Rainfed Areas. The webinar highlighted the results of on-farm generation and verification trials conducted from 2017 to 2021 as well as the fine-tuning of the machine, and technology dissemination strategies.

Figure 7. Project implementers grace the National Forum.

A survey was conducted after the forum to determine participants' feedback:

- Order of topic presentation, "Excellent", 56%;
- Speakers' clarity and delivery of topics, "Very Good", 40%;
- Time management and supervision of activity, "Excellent", 48%;
- Relevance of the webinar in participant's work, "Excellent", 75%;
- Usefulness of information learned, "Very Good", 43%;
- Applicability of the webinar to improve the well-being of target users, "Excellent", 64%;
- Opportunity to learn through interaction with speakers and other participants, 47%;
- For raising the consciousness of participants on mechanized dry direct seeding technology as tool to improve farm productivity; "Very Good", 44%; and
- Overall satisfaction rating of 44% in conducting the webinar, "Excellent".

C. Capacity Building

C.1 Specialized Course on MP Seeder Operation, Troubleshooting, and Maintenance

To enhance the capacity of partners (farmer-cooperators, LGUs, and researchers), the specialized course was conducted using the MP Seeder Operations Manual as guide (Figure 9). Lectures with hands-on demonstration in the field were done by resource persons from DA-PhilRice and International Rice Research Institute (IRRI).

Four batches of trainees with a total of 112 participants (96 men, 16 ladies) finished the specialized course conducted in South Cotabato, Ilocos, DA-PhilRice CES, and Iloilo. To assess their gain in knowledge (GIK), pre- and post-tests were conducted on: (1) proper layout of MP Seeder; (2) proper maneuvering; (3) changing of seed plates; (4) proper troubleshooting; (5) maintenance and storage. Participants' self-assessment shows that capability on changing of seed plates (47.4%), and proper troubleshooting (41.2%) got the highest ratings, with overall average GIK at 40.8% (Figure 8).

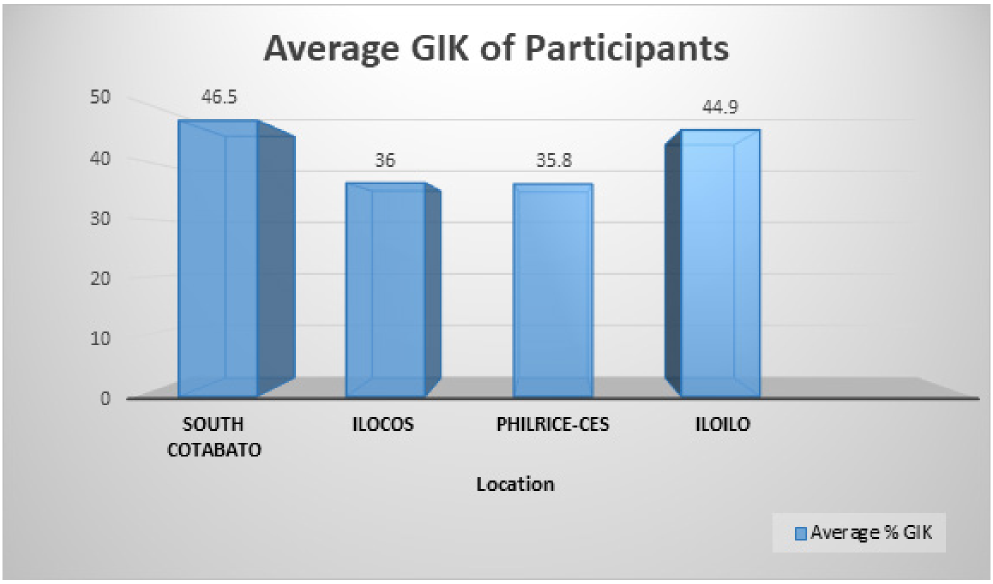

Figure 8. Average gain in knowledge of the participants.

Figure 9. Training on Machine Operation, Troubleshooting, and Repair and Maintenance.

C.2. Hands-on training on conducting on-farm verification trials

Local partners (12 men, 6 ladies) from Regions 1-6, and 12 participated in the November 11-12, 2020 training to enhance their skills in proper field layouting and collection of agronomic data for rice and corn (Figures 10-11).

Figure 10. Training on technology generation and verification, layouting, and agronomic data collection.

C. 3. Technical briefing

Figure 11. Technical briefing for machine fabricators and technicians.

In 2020, the following activities were conducted in support of the uptake pathways for MDDS in partnership with machine fabricators and technicians:

- Linkage-building and strengthening with fabricators and manufacturers, and partner-agencies in Regions 1 including Abra, 2, 3, 5, 6, and 12 through renewal of Memorandums of Agreement (MOA);
- Capacity building to enhance the skills of MP Seeder partners and collaborators in setting-up on-farm research and verification trials, monitoring and collection of agronomic data, and to standardize procedures;
- Renewed MOA with Isabela and Cagayan together with DA-RFO 2 through Southern Cagayan Research Center (SCRC), and Cagayan State University (CSU) Lal-lo Campus;
- Technical briefing in Camiling, Tarlac with 15 participants (12 men, 3 ladies)
- Some meeting highlights:
    1. All manufacturers will enter into a licensing agreement with PhilRice.
    2. Each manufacturer will produce a commercial unit based on the PhilRice standard design, and should be AMTEC-tested.

In 2021, several major activities were rolled out to massively disseminate MDDS as discussed in detail below:

Bridging innovations to market pathways through commercialization

In compliance with Republic Act No. 10055 (Philippine Technology Transfer Act of 2009) that aims to promote and facilitate the transfer, dissemination, and effective use, management, and commercialization of intellectual property, technology and knowledge resulting from R&D funded by the government for the benefit of the national economy and taxpayers, consultation meetings were conducted with concerned machine fabricators (Figure 12). An orientation on the law was made part of the meetings to enlighten selected fabricators and DA-PhilRice staff on the documents required by the DOST-Fairness Opinion Board (FOB). Legal and technical assistance from the Intellectual Property Management Office and the Business Development Division of DA-PhilRice, respectively, were sought to facilitate the discussion and preparation of documents.

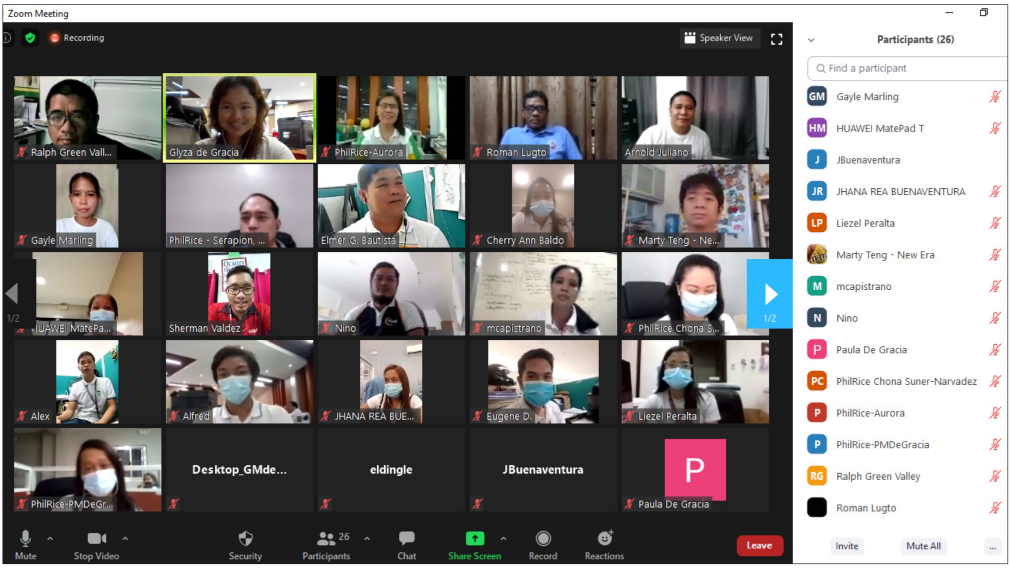

Figure 12. Screenshot of participants

Commercialization, the process of deriving income or profit from a technology, which ensures the accessibility and availability of the MP Seeder to the public, will commence once the Technology License Agreement (TLA) is signed by both DA-PhilRice and manufacturers.

Request letters were directed to DOST for favorable written recommendation and Fairness Opinion Report (FOR) for the proposed non-exclusive licensing of the MP Seeder to the following companies: (1) ACT Corporation, (2) New Era Industries, (3) Globall Marketing and Construction Corp. and (4) Green Valley Machineries.

FOB meetings to transfer the MP Seeder technology to manufacturers were conducted (Table 1). FORs were released on July 28 and September 9, 2021 whereby the proposed transaction of DA-PhilRice to transfer the technology to manufacturer is deemed fair to both parties. The transaction relates to the proposed direct non-exclusive licensing of the Multi-Purpose Seeder covered by registered utility mode l2/2017/050345 (‘345, filed December 29, 2017) to the manufacturers who agreed to a one-time upfront fee of PhP 10,000 and 3% royalties on gross sales for a 3-year term.

Table 1. Series of FOB meetings to transfer the MP Seeder technology to manufacturers.

Series of FOB meetings	Date	Manufacturer	Release of FOR
1st Request for presentation of technologies	July 12, 2021	ACT (Machineries & Metalcraft) Corp.	July 28, 2021
2nd Proposed transaction of PhilRice to transfer the technology of Multi-Purpose Seeder to ACT Machineries	July 28, 2021		
Proposed transaction of DA-PhilRice to license the technology "Multipurpose Seeder"	August 19 and 27, 2021	New Era Industries, Green Valley Machineries, and Globall Marketing and Construction Corp.	September 9, 2021

The TLA stipulates that the licensee (manufacturer) has formally expressed its interest and intent in commercially manufacturing and marketing the MP Seeder. Table 2 shows the list of licenses manufacturer of MP Seeder in the Philippines

Table 2. List of licensed manufacturers of MP Seeder.

Region	Name of Manufacturer	Location	Remarks
1	New Era Industries	Laoag City, Ilocos Norte	Signed TLA on Dec. 10, 2021
2	ACT (Machineries & Metalcraft) Corp.	Cauayan City, Isabela	Signed TLA on Sept. 21, 2021
3	VAL Agri-Machineries & Machine Shop	Guimba, Nueva Ecija	Co-inventor
NCR	Globall Marketing & Construction Corporation	Tunasan, Muntinlupa City	Signed TLA on Dec. 10, 2021
12	Green Valley Machineries	Koronadal City, South Cotabato	Signed TLA on Dec. 10, 2021

In support of efforts to transfer and commercialize technologies generated from government-funded R&D initiatives, the MP Seeder team participated in the 1st DOST-DA Technology Transfer Forum on September 30, 2021 (Figure 13). In its featured pitching session, technology generators and transfer officers from various R&D institutions, and the academe had the opportunity to present their innovations and business ideas to potential investors.

Figure 13. Project lead Elmer G. Bautista during the Technology Transfer Forum.

Takeaways

- Certain farmers are still more comfortable with manual dry direct seeding as they can do it with some level of precision learned over long years of field experience. Also, they need not worry about expensive fuel.

- Well-pulverized soil is necessary for good crop establishment using the MP Seeder, which explains why there are some difficulties in using the machine in clay soil. This soil has much large percentage of clay particles that are quick to harden and cannot be easily penetrated by the furrow opener of the machine.

- Using the MP Seeder is highly recommended in areas with limited water supply but have high potential for short-term cash crops such as corn and mungbean.

- Intensified promotion of direct seeding using the machine is necessary to reach out to more farmers especially those in remote areas needing technical services from government.

- More farmers in adverse areas can benefit from MP Seeder if it could be integrated in the RCEF machine component.

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