EFFECT OF DIFFERENT SEED PRIMING METHODS ON PERFORMANCE OF DIRECT BROADCAST SEEDED RICE (DBSR) IN CHITWAN, NEPAL

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Abstract. Direct broadcast seeded rice (DBSR) requires uniform plant population and faster establishment throughout the field for higher productivity. A field experiment was conducted at Agronomy farm of AFU Rampur, Chitwan during rainy season of 2019 to evaluate seed priming on the growth and productivity of DBSR. The treatments consisted of four priming methods {Control (no-priming), Hydro-priming (24 hrs tap water soaking + 12 hrs shade drying), KCl priming (24 hrs solution soaking, @ 20.74 g/ltr + 12 hrs shade drying), $CaCl_2$ priming (24 hrs solution soaking , @ 22.2 g/ltr + 12 hrs shade drying) } which were tested on two different seed rates (60 kg ha^{-1} and 30 kg ha^{-1}) of two rice varieties { Hybrid (Gorakhnath-509) and Inbred (Sabitri)} in split-split plot design with four replications. The research results showed that priming resulted uniform plant population, faster crop establishment and better crop productivity. The average of 3660 kg ha^{-1} grain yield was obtained due to priming in this experiment. Hybrid (Gorakhnath-509) recorded higher grain yield (3714 kg ha^{-1}) than the high yielding inbred (Sabitri) (3606 kg ha^{-1}). Higher grain yield in hybrid (Gorakhnath-509) was attributed to vigorous crop growth with significantly higher LAI ensuring more photosynthesis, more AGDM production, more number of grains per panicle and more effective tillers per meter square than inbred (Sabitri). The highest grain yield (4132 kg ha^{-1}) was obtained in $CaCl_2$ priming. The grain yield of $CaCl_2$ priming was significantly higher than all other priming treatments and the grain yield of KCl priming was also higher than hydro-priming and control. The lowest grain yield (3369 kg ha^{-1}) was observed in non-priming. Grain yield in priming techniques ranged from 3369 to 4132 kg ha^{-1}. Higher seed rate (60 kg ha^{-1}) gave significantly higher yield (4389 kg ha^{-1}) than lower seed rate (30 kg ha^{-1}). Therefore, hybrid seed, higher seed rate and all the priming treatments produced better yield than non-priming. Doing priming treatment in direct broadcast seeded rice gave uniform plant population, faster crop growth and better crop yield and this system can be easily adopted by Nepalese farmers because this system is more economic by sowing seeds through broadcast method in absence of seed drill machine for sowing seeds in line in Dry DSR.

Keywords: Direct broadcast seeded rice, priming, plant population, crop establishment, crop productivity, photosynthesis, inbred, Dry DSR

Abbreviations
AGDM-Above Ground Dry Matter
LAI-Leaf Area Meter
DBSR-Direct Broadcast Seeded Rice
DSR-Dry Seeded Rice

INTRODUCTION

Rice (*Oryza sativa L.*) is one of the most popular cereal crops in the world. It is one of the most important staple foods for more than 3.5 billion people in the world (CGIAR, 2016). Over 90 percent of the world's rice is produced and consumed in Asia (Mohanty, 2015). It is the main staple food in at least 33 developing countries, and it accounts for 27% of dietary energy supply, 20% of dietary protein and 3% of dietary fat (FAO, 1999).

In Nepal, rice stands for first position in terms of area (1.47 M ha) and production (5.13 M tonnes) with an average productivity of 3.47 t ha^{-1} (www.aitc.gov.np, 2022). It contributes 27% to the total AGDP and 7% to the national GDP (CDD, 2017). It fulfils 50% of the total grain requirement and 30% of the total calorie requirement of the country (Dhungel and Acharya, 2017).

In Nepal, rice is largely produced from irrigated system with conventionally transplanted flooded culture and rainfed system. TPR system needs more water, labors and draft energy for puddling. Scarcity of water is on the increasing trend and the excessive dependence on ground water due to poor irrigation system are leading to declining of ground water table resulting in higher cost of pumping aggravating energy crisis. Heavy machine used in TPR system destroys the soil physical properties by dismating the soil aggregates and ultimately affects the growth and productivity of succeeding wheat crop as there is formation of hard pan at shallow depths (Kakraliya et al., 2018). It leads to high losses of water through puddling, surface evaporation and percolation.

Dry direct seeded rice (dry DSR) is alternative system to transplanting system in terms of water use and labor cost. It avoids puddling and transplanting of young seedling and requires less water, labor, time, drudgery and cultivation cost (Chakraborty et. al., 2017). The direct seeded rice matures 7-10 days earlier than the transplanted rice system productivity. Similarly, the grain yield from the DSR is comparable with that from the transplanted rice if managed properly (Gill, Walia & Gill, 2014).

There is uneven crop stand in DDSR due to poor seed germination and seedling growth and high weed infestation. Deficiencies of micronutrients such as Zn and Fe due to imbalanced N fertilization and high infiltration rates in DSR are of major concern (Gao et al., 2006). These are critical constraints affecting subsequent growth and yield and create hindrance in its adoption at farmer's field (De Datta, 1986; Farooq et al., 2011). This system is more mechanized type which needs specific seed drill machine for uniform seed placement that can't be afforded by Nepalese poor farmers. Direct broadcast seeded rice (DBSR) system is suitable for Nepalese farmer because it is suitable for small land holding farmers, less mechanization, less labor needed, low cost technology and highly affordable for Nepalese farmers. But there are also some problems like non- uniform seedling emergence, low plant population, less establishment of seedlings, slow growing of seedlings, seeds on surface eaten by birds, deep seeded rots, seeds not uniformly distributed, less seeds and soil contact reduce germination.

The priming techniques have capacity to improve germination and seedling emergence and involve physiological implication for improved growth and to some extent on yield and quality attributes of direct seeded rice. Seed priming with KCl or $CaCl_2$ have been reported to improve the seedling growth in nursery transplanted and stand establishment as well as yield performance in direct seeded rice (Farooq et al., 2006). The primed crops emerge faster and more completely, produce more vigorous seedlings, flower and mature earlier and yield better than non-primed crops. Early emergence of vigorous crop stand provides better root anchorage and improves nutrient absorptive capacity. Priming is a low risk technology, which can give high returns when adopted at farmer's field. Therefore, the main problem to be addressed by this research project is to improve rate, uniformity and percentage of seedling emergence which is successed by seed priming techniques, better weed control and avoiding higher risk of poor seedling establishment through seed rates, early emergence of seedlings even under crust conditions by selecting cultivars having good mechanical strength in the coleoptiles, affordable sowing method (DBSR) by Nepalese farmers instead of highly mechanized dry DSR.

MATERIALS AND METHODS

Description of the experimental site. A field experiment was conducted in the field of Agriculture and Forestry University in Rampur, Chitwan Nepal during rainy season of 2019. This site is located at 9.8 km South-West from Bharatpur. Geographically, this experimental location falls in the inner Terai region of Central Development Region of Nepal.

Soil physico-chemical properties of experimentation site

Soil samples was taken randomly from four different spots of each replication from the depth of 0-15 cm soil layer using tube auger to record the initial physico-chemical properties of experimental site. The sample was dried and a portion of that was sieved through 0.5 mm sieve for organic matter determination and another portion of that through 2 mm sieve for other physico-chemical properties of the soil.Î

Table 1

Physico-chemical properties of soil of the experimental sites

S.N.	Properties	Average content	Category
1.	Physical properties		
	Sand (%)	62.70	-
	Silt (%)	28.50	-
	Clay (%)	9.10	-
2.	Chemical properties		
	Soil Ph	5.28	Acidic
	Soil organic matter (%)	3.41	Medium
	Total nitrogen (%)	0.18	Medium
	Available phosphorus (Kg ha^{-1})	46.76	Medium
	Available potassium (Kg ha^{-1})	83.83	Low
3.	Textural class (USDA textural triangle)	-	Sandy loam

Weather condition during the course of experimentation.

The experimental site has humid and subtropical climate with cool winter (2-3 ^{0}C) and hot summer (43 ^{0}C). The annual rainfall is over 1500 mm with a distinct monsoon period (more than 75% of annual rainfall) from mid-June to mid-September (NARC, 2015). The climate is characterized by three distinct seasons; rainy season

(June to Oct), cool winter (Nov to Feb) and hot spring (March to May). All the required metrological data during the experimentation were taken from the metrological station of National Maize Research Program (NMRP), Rampur, Chitwan.

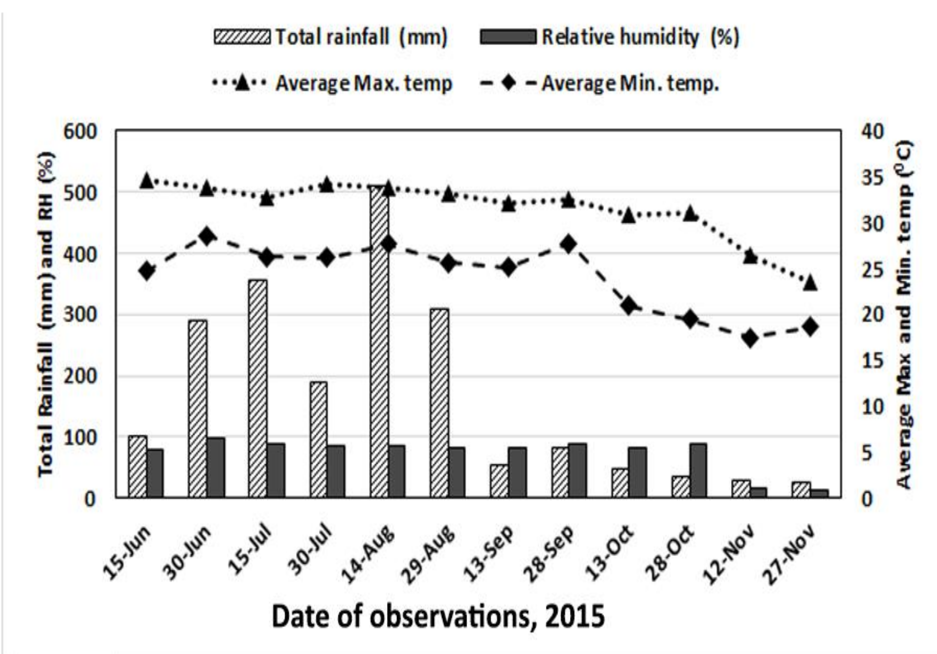

Fig. 1. Weather data during the experimentation period at AFU, Rampur, Chitwan, Nepal from June to November, 2019 (Source: NMRP, 2019)

Experimental details. The experiment was laid out in split-split plot design with four replications having 16 treatment combinations.

Treatment details

Main plot factor (Varieties):
V1 = Gorakhnath-509 (Hybrid)
V2 = Sabitri (High yielding variety)
Sub plot factor (seed rates):
S1 = 60 kg ha^{-1}
S2 = 30 kg ha^{-1}
Sub-sub plot factor (Seed priming methods):
P_1 = Control (No-priming)
P_2 = Hydro-priming (24 hrs tap water soaking + 12 hrs shade drying)
P_3 = KCl priming (24 hrs solution soaking @ 20.74 g/ltr + 12 hrs shade drying)
P_4 = $CaCl_2$ priming (24 hrs solution soaking @ 22.2 g/ltr + 12 hrs shade drying)

Land preparation and layout of the field

The land of Agronomy farm previously used for research activities was used for the experiment. Cross plowing was carried out with tractor for the good tilth. Land was cleaned by removing the weed and crop residues. Whole research plot and individual sub plot were prepared according to preset measurements and layout design. Water channels were well maintained. The experiment plots were prepared with manual labor.The source of chemical fertilizers were urea (46% N), DAP (18% N and 46% P_2O_5), MOP (60% K_2O), and Zinc Sulphate (21% Zn, @ 20 kg ha^{-1} $ZnSo_4$). The potash (as MOP), phosphorus (as DAP) and Zinc sulphate were applied as basal to all the 64 plots. For the plots receiving recommended dose (120:60:60 NPK kg ha^{-1}), nitrogen was applied in three equal splits i.e 1/3 at active tillering stage and 1/3 at PI stage and all P and K was applied as basal.

Sowing

The seed was sown on 16th June, 2019 just after the initial pre monsoon rainfall. Broadcasting method was used to keep seeds in the field which was done manually. Seed rate of 60 kg ha^{-1} and 30 kg ha^{-1} was used in the experiment. Amount of seed required for each individual plot will be calculated and recommended amount of bavistin was used to seeds to produce healthy seedlings and sown through broadcasting method. After broadcasting, cover the seeds using a spike-tooth harrow.

Weeding

The pre emergence herbicide pendimethalin was sprayed just after 2 days of seed sowing at the rate of 1 kg a.i. ha^{-1} to control the early stage narrow leaved weeds. Likewise, two hand weeding were done in the plots to reduce the competition between weeds and crop for nutrients and to optimize the crop performance. First weeding was done at 20 DAS and second weeding was carried out at 45 DAS.

Irrigation

The crop was grown under rainfed condition. The pre monsoon rainfall provided the sufficient moisture for crop establishment and later the monsoon rainfall supplied the additional required moisture level for the crop.

Harvesting and threshing

The crop from the net plot area was harvested manually with the help of sickle. Harvested plants were left in situ in the field for 3 days for sun drying. First harvesting was carried out for Gorakhnath-509 and Sabitri variety in next harvesting time as they matured on different ime. Threshing was done with paddle thresher. Threshed grains were cleaned by winnowing. The moisture content of grain was taken with moisture meter and weight of each plot was taken with digital balance.

Data analysis. All the collected data were entered in MS excel and analysis was done by using Computer software statistical package R.

RESULTS AND DISCUSSIONS

1. Biometrical observations

Plant height

$CaCl_2$ priming produced significantly taller plants than non-priming at 45 and 105 DAS but not significantly at 60, 75, and 90 DAS. Plant height of all priming treatments was statistically similar at 60, 75 and 90 DAS. At 45 DAS, plant height was statistically different among all priming treatments. At 105 DAS, plant height of $CaCl_2$ priming and KCl priming was statistically similar. Similarly, it was also statistically similar in case of KCl priming and Hydro-priming but plant height of non-priming was significantly differed from all priming treatments at the same date. It was also reported by Jie, Dong, Fang & Hua (2002).

Table 2

Effect of priming methods on plant height of DBSR

Treatments	Plant height (cm)				
	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
Priming					
Control	27.35[d]	62.27	72.96	79.89	90.25[c]
Hydro-priming	31.06[c]	63.42	72.25	77.79	97.41[b]
KCl	33.37[b]	63.91	72.51	79.44	98.38[ab]
$CaCl_2$	35.57[a]	62.76	72.95	81.07	98.69[a]
SEm (±)	0.277	1.247	0.990	1.696	0.396
LSD (0.05)	0.794	Ns	Ns	Ns	1.137
CV, %	3.5	7.9	5.5	8.5	1.6
Grand mean	31.84	63.09	72.67	79.55	96.18

Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan Multiple Range Test

Number of tillers per square meter

The numbers of tillers per square meter with $CaCl_2$ were significantly different from non-priming at 45, 60, 75 and 90 DAS except 105 DAS. Significant influence of priming was observed in tiller mortality with mean of 48.18 %.

Table 3

Effect of priming methods on number of tillers per square meter of DBSR

Treatments	No of tillers (m^{-2})					Tiller Mortality(%)
	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	
Priming						
Control	187.6[c]	209.4[b]	316.1[c]	177.1[c]	160.2	49.91[a]
Hydro-priming	211.1b[c]	233.6[b]	347.6[b]	206.9[b]	168.8	48.00[b]
KCl	227.9[b]	235.2[b]	349.8[b]	212.1[b]	175.0	47.91[b]
$CaCl_2$	258.1[a]	284.2[a]	394.5[a]	249.8[a]	192.2	46.88[b]
SEm (±)	10.15	9.33	7.98	7.48	10.51	0.37
LSD (0.05)	29.11	26.77	22.88	21.46	Ns	1.08
CV, %	18.4	15.5	9.1	14.1	24.1	3.1
Grand mean	221.2	240.6	352.0	211.5	174.1	48.18

Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan Multiple Range Test

Leaf area index (LAI)

$CaCl_2$ resulted significantly higher LAI than non-priming methods at all the dates of observation. Also, the differences among the LAIs of priming treatments were non-significant at all the dates of observations except 45 DAS.

More LAI in $CaCl_2$ treatment was due to higher CGR where the process of cell division and elongation higher and ultimately increased the leaf number and leaf area reported by Horie, Lubis, Takai, Ohsumi, Kuwasaki, Katsura & Nii (2003). The decline in LAI after 75 DAS was mainly due to the senescence of lower leaves. Chandrasekhar, Rana Rao, Ravindranath & Reddy (2001) also observed decrease of leaf area (due to senescence of early formed leaves) after initiation of panicle which was associated with the remobilization of stored metabolites from leaf sheath and stem to panicles. There are strong positive correlation (0.90**) between the LAI and grain yields at 75 DAS.

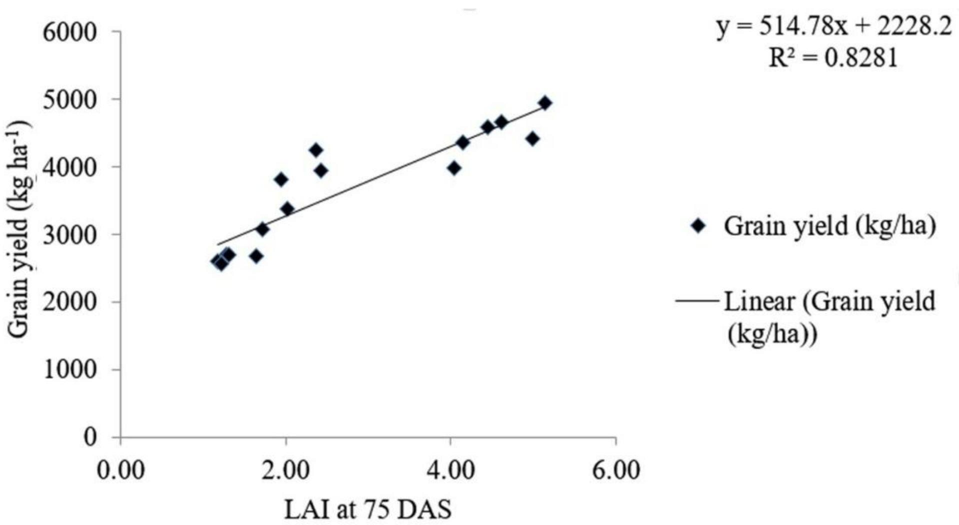

Fig. 2. Relationship between LAI at 75 DAS and grain yield of DBSR

Table 4

Effect of priming methods on LAI under DBSR

Treatments	LAI				
	45 DAS	60 DAS	75 DAS	90 DAS	105DAS
Priming					
Control	0.62^c	1.48^b	1.82^c	1.73^b	1.48^b
Hydro priming	0.72^b	1.76^b	2.68^b	1.84^b	1.62^b
KCl	0.77^b	1.96^{ab}	3.11^{ab}	2.27^{ab}	1.80^{ab}
$CaCl_2$	0.95^a	2.32^a	3.53^a	2.50^a	2.06^a
SEm (±)	0.03	0.16	0.18	0.19	0.14
LSD (0.05)	0.08	0.47	0.51	0.54	0.41
CV, %	14.6	34.8	25.6	36.4	32.5
Grand mean	0.76	1.88	2.78	2.09	1.74

Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan Multiple Range Test

Above ground dry matter (AGDM)

$CaCl_2$ priming, KCl priming and hydro-priming produced significantly higher AGDM than non-priming at all dates of observation except at 60 DAS. Generally, $CaCl_2$ priming produced higher AGDM than other priming methods but significantly only at 45 DAS. Olugbemi, Mutayoba & Lekule (2010) repotted that dry matter (DM) values increased in primed seeds as compared to non-primed seeds. Primed seeds result in increased dry matter production at vegetative stage due to continuous gain in plant height, number of branches and uniform stand.

Table 5

Effect of priming methods on above ground dry matter (AGDM) under DBSR

	AGDM (g/m^2)				
Treatments	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
Priming					
Control	89.49[c]	160.31[b]	219.13[c]	254.86[c]	357.37[c]
Hydro priming	103.84[b]	183.60[b]	353.20[b]	391.23[b]	496.44[b]
KCl	111.60[b]	229.40[a]	415.85[a]	445.37[a]	549.87[a]
$CaCl_2$	138.37[a]	241.68[a]	449.84[a]	476.77[a]	580.07[a]
SEm (±)	4.056	10.40	16.44	11.08	11.83
LSD (0.05)	11.632	29.85	47.15	31.78	33.94
CV, %	14.6	20.4	18.3	11.3	9.5
Grand mean	110.82	203.75	359.51	392.06	495.94

Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan Multiple Range Test

Linear relationship was observed between AGDM at 90 DAS and grain yield with strong correlation coefficient (r = 0.902**).

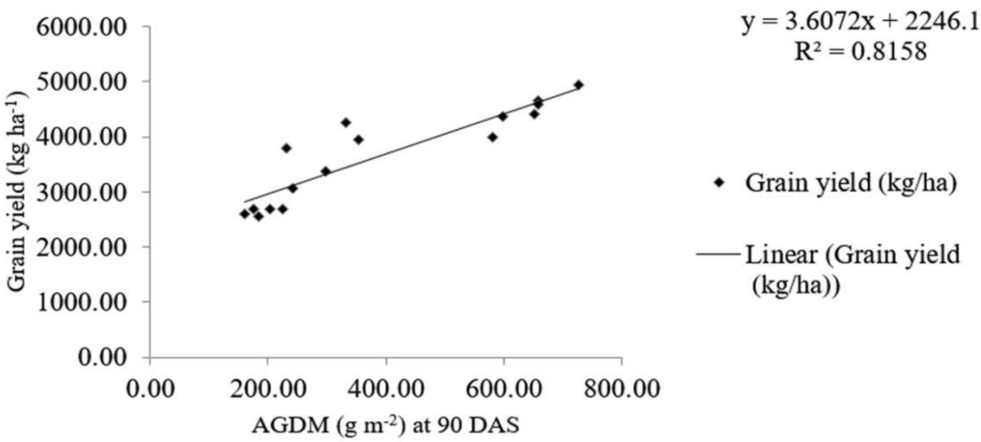

Fig. 3. Relationship between AGDM at 90 DAS and grain yield of DBSR

2. Yield attributing characters

Number of effective tillers per square meter (ETm^{-2})

The treatments receiving priming with $CaCl_2$ produced significantly higher effective tillers per square meter than other priming treatments. The lowest ET m^{-2} (158) was recorded in non-priming. Osmo-priming helped not only improving seedling establishment but also helped increase yield of dry direct seeded rice by improving the yield attributes such as number of panicle m^{-2} and grains $panicle^{-1}$. Similar result was reported by Islam, Mukherjee & Hossin (2012) and Takhti & Shekafandeh (2012).

There was strong positive correlation (r = 0.896**) between effective tillers per square meter and grain yield (Figure 3).

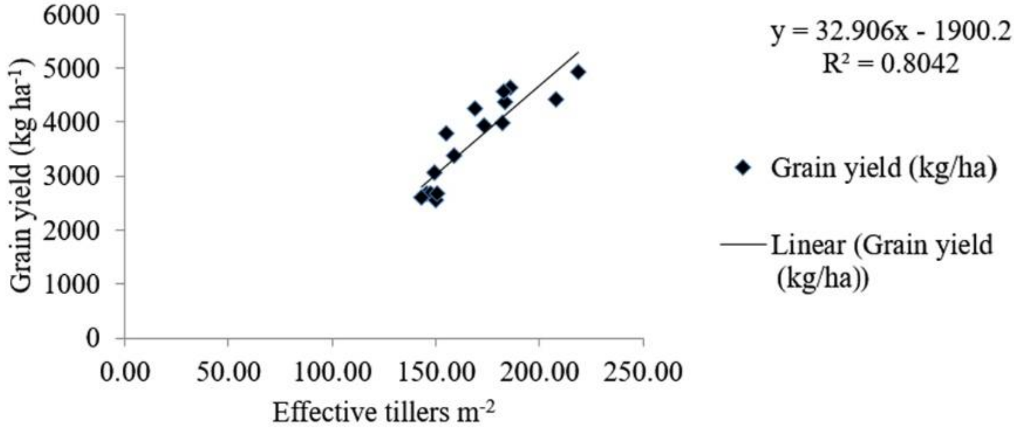

Fig. 4. Relationship between effective tillers per square meter and grain yield of DBSR

Number of grains per panicle

The $CaCl_2$ priming produced significantly higher number of grains per panicle than KCl priming, hydro-priming and control. The lowest number of grains per panicle was recorded in non-priming. Priming techniques improve CGR. Horie et al. (2003) reported that higher CGR improve the formation of non-structural carbohydrate (NSC) and spikelet number during late reproductive stage.

There was positive correlation ($r = 0.192^{ns}$) between grain yield and number of grains per panicle. Shrirame & Muley (2003) also concluded that rice grain yield was positively correlated with number of grains per panicle.

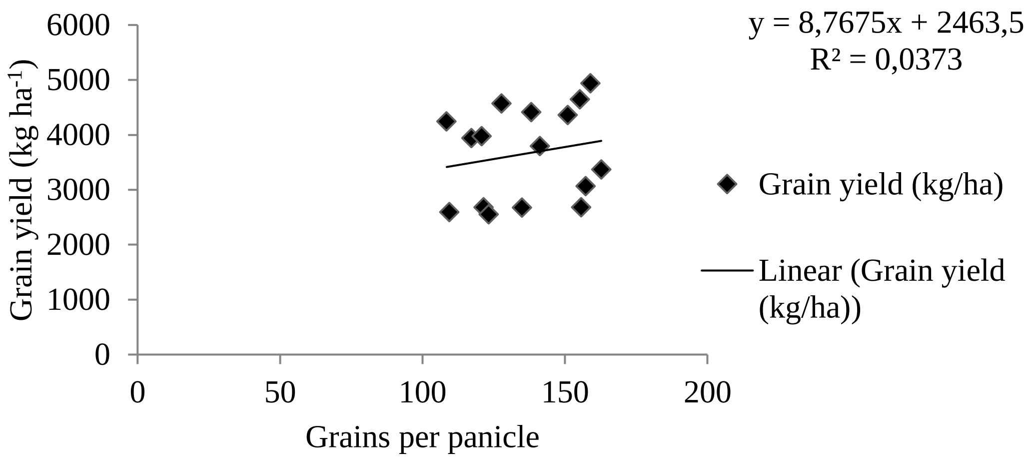

Fig. 5. Relationship between grains per panicle and grain yield of DBSR

Sterility percentage

Statistically higher panicle sterility was found in non-priming than priming treatments either through $CaCl_2$ priming, KCl priming or hydro-priming. The panicle

sterility in priming treatments ranged from 14.91 % to 19.07 % whereas it was 30.45 % in non-priming.
There was negative linear correlation between grain yield and sterility percentage.

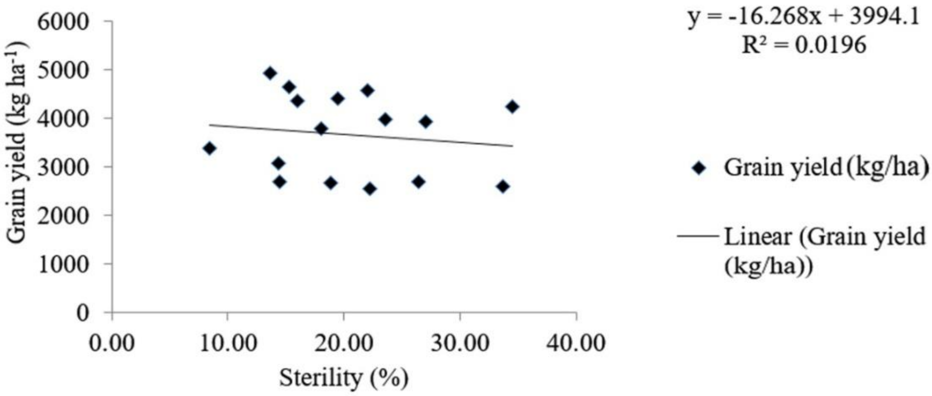

Fig. 6. Relationship between sterility percent and grain yield of DBSR

Panicle length

$CaCl_2$ had significantly higher panicle length than panicle length of KCl priming, hydro-priming and non-priming. The lowest panicle length was observed in hydro-priming followed by non-priming.
There was positive linear correlation (r=0.089^{ns}) between grain yield and panicle length.

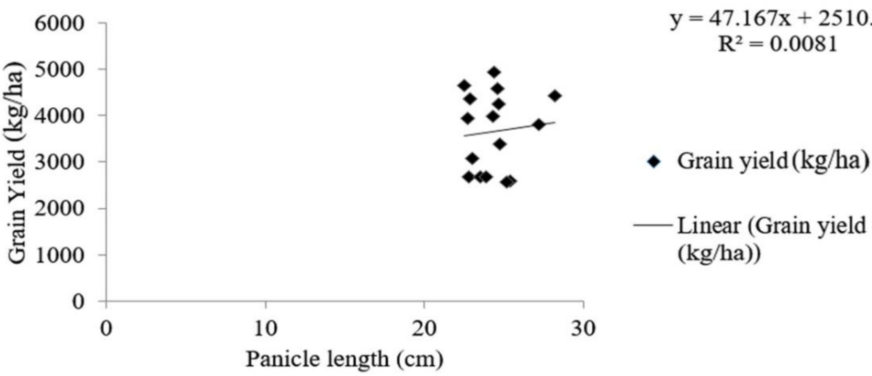

Fig. 7. Relationship between panicle length and grain yield of DBSR

Thousand grains weight (TGW)

Statistically different TGW was observed in all priming treatments. Higher CGR during heading to maturity accumulate carbohydrate which moves towards the panicle side and contribute in reducing spikelet sterility and increasing grain weight penicle^{-1} (Ntanos & Koutroubas, 2002). It was also reported by Murchie, Yang, Hubbart, Horton & Peng (2002).

There was positive correlation (r = 0.126^{ns}) between the TGW and grain yield.

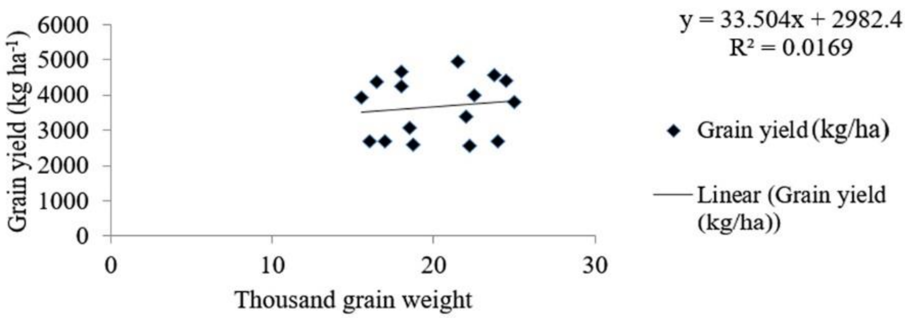

Fig. 8. Relationship between thousand grain weight and grain yield of DBSR

Table 6

Effect of priming methods on yield attributing characters under DBSR

Treatments	Yield attributing characters					
	ET/ m^2	Sterility (%)	TGW (g)	Panicle length (cm)	Panicle weight (g)	Grains/ Panicle
Priming						
Control	158^b	30.45^a	17.06^d	23.94^b	2.330^c	23.94^b
Hydro priming	166^b	19.07^b	19.56^c	23.92^b	2.612^b	23.92^b
KCl	167^b	17.64^b	21.06^b	23.54^b	2.679^b	23.54^b
CaCl2	185^a	14.91^c	23.25^a	26.09^a	2.987^a	26.09^a
SEm (±)	3.9	0.69	0.16	0.24	0.06	0.24
LSD (0.05)	11.1	1.97	0.47	0.19	0.18	0.19
CV, %	9.1	13.5	3.3	4.0	9.9	4.0
Grand mean	169	20.52	20.234	24.37	2.652	24.37

Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan Multiple Range Test

Panicle weight

Significantly $CaCl_2$ priming produced higher panicle weight than other priming treatments. Panicle weight of KCl priming and hydro-priming was statistically similar but significantly differed from non-priming. Priming treatments enhance CGR and reduce ethylene production where grain filling period is higher (Mohapatra & Mohapatra, 2005; Yang et al., 2006) that improves grain size and panicle weight.

There was positive correlation ($r = 0.324^{ns}$) between panicle weight and grain yield (Figure 8).

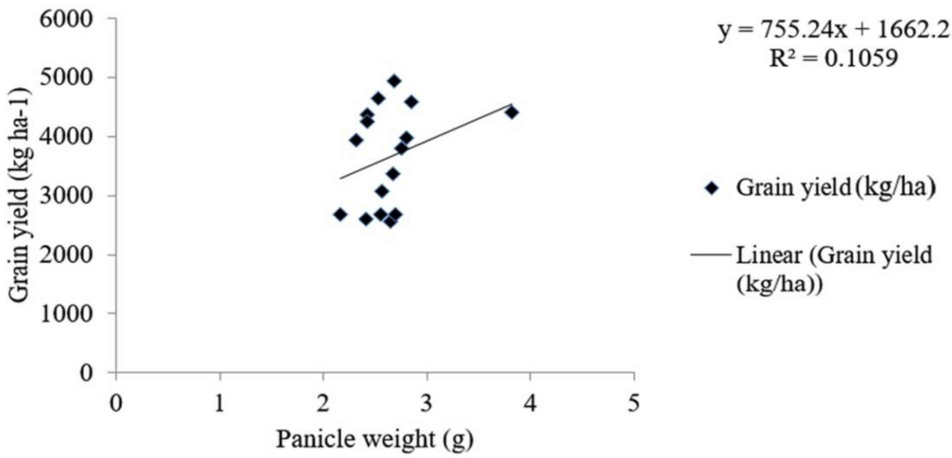

Fig. 9. Relationship between panicle weight and grain yield of DBSR

3. Grain and straw yields as influenced by priming methods

Grain yield

The highest grain yield (4132.00 kg ha^{-1}) was obtained in $CaCl_2$ priming. The grain yield of $CaCl_2$ priming was significantly differed from KCl priming. Yields of both these priming were also significantly differed from yields of both hydro-priming and non-priming. The Grain yields of both hydro-priming and non-priming were statistically similar. The lowest grain yield (3369.00 kg ha^{-1}) was observed in non-priming. Grain yield in priming techniques ranged from 3369 to 4132 kg ha^{-1}.

Table 7

Effect of priming methods on grain yield and straw yield under DBSR

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Priming		
Control	3369^{c}	4480^{b}
Hydro-priming	3396^{c}	4440^{b}
KCl	3744^{b}	5000^{a}
$CaCl_2$	4132^{a}	5400^{a}
SEm (±)	107.2	177
LSD (0.05)	307.3	508
CV, %	11.7	14.7
Grand mean	3660	4830

Means followed by the same letter(s) in the same column are not significantly different at 5% probability level by Duncan Multiple Range Test

Straw yield

The highest (5400 kg ha^{-1}) and the lowest (4480 kg ha^{-1}) straw yields were observed in $CaCl_2$ priming and non-priming respectively while the average straw yield in this experiment was 4830 kg ha^{-1}. Straw yields of $CaCl_2$ and KCl priming were statistically similar. Straw yields of $CaCl_2$ and KCl were significantly differed from hydro-priming and non-priming.

There was positive strong correlation between straw yield and grain yield.

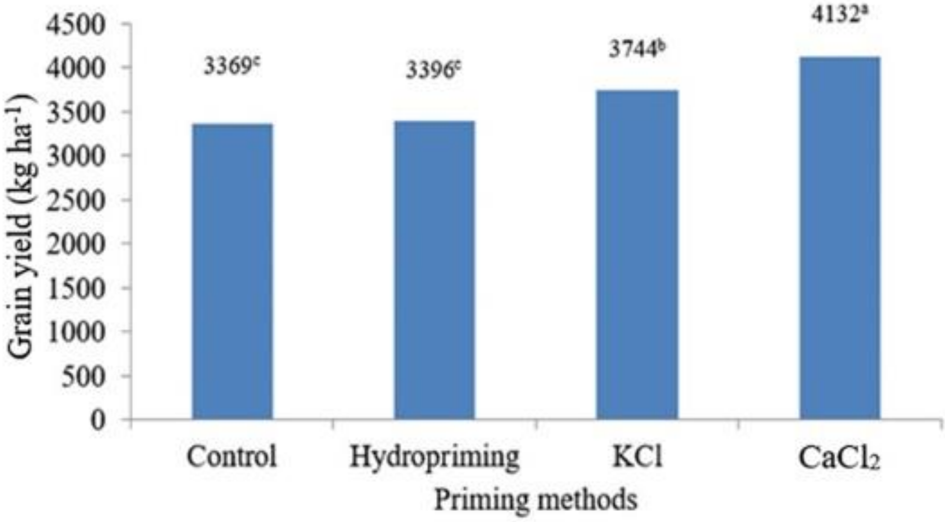

Fig. 10. Grain yield of DBSR as influenced by priming methods

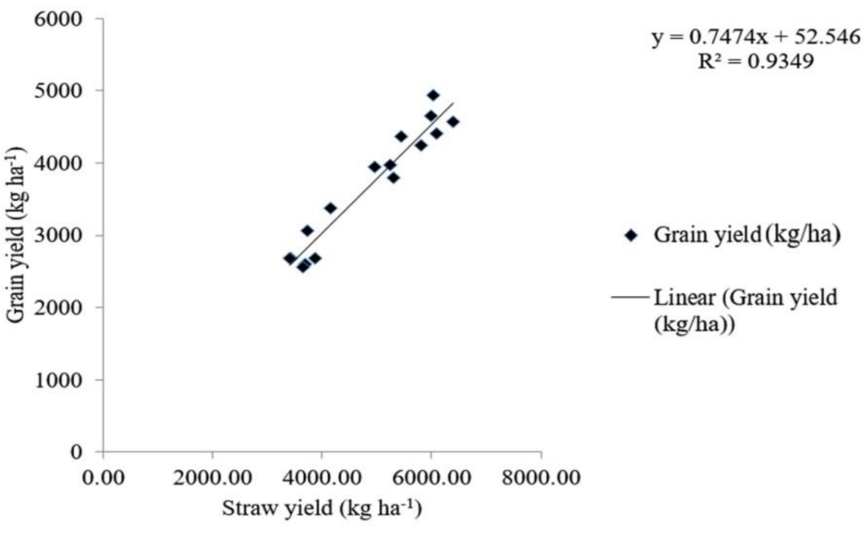

Fig. 11. Relationship between straw yield and grain yield of DBSR

CONCLUSIONS

Seed priming methods helped to enhance the performance of direct broadcast seeded rice. Osmo-hardening with $CaCl_2$ was found as the most effective priming technique to improve the crop stand, growth, yield, and quality of direct broadcast seeded rice. Nonetheless, more research efforts and participatory evaluation of the priming techniques in direct broadcast seeded rice are needed to uplift rice yield for the Nepalese farmers.

REFERENCES

1. CDD. (2017). Rice Science and Technology In Nepal. (M. N. Paudel, D. R. Bhandari, B. K. Joshi, P. Acharya, & K. H. Ghimire, Eds.) Kathmandu: Crop Development Directorate (CDD) and Agronomy Society of Nepal (ASoN).
2. CGIAR. (2016). The global staple. http://ricepedia.org/rice-asfood/the-global-staple-rice-consumers
3. Chakraborty, D., Ladha, J. K., Rana, D. S., Jat, M. L., Gathala, M. K., Yadav, S., et al. (2017). A global analysis of alternative tillage and crop establishment practices for economically and environmentally efficient rice production. Sci. Rep. 7, 9342. doi: 10.1038/s41598-017-09742-9
4. Chandrasekhar, J., Rao, G. R., Reddy, B. R., & Reddy, K. B. (2001). Physiological analysis of growth and productivity in hybrid rice (Oryza sativa L.). *Indian Journal of plant physiology*, *6*(2), 142-146.
5. De Datta, S. K. (1986). Technology development and the spread of direct-seeded flooded rice in Southeast Asia. *Experimental agriculture*, *22*(04), 417-426.
6. Dhungel, S., & Acharya, P. (2017). Role of Rice in Food and Nutrition Security in Nepal. In Rice Science and Technology in Nepal (pp. 77-85).
7. FAO. (1999). The state of food insecurity in the world. Food and Agriculture Organization of the United Nations, Rome Italy.
8. Farooq, M., Basra, S. M. A., Tabassum, R., & Afzal, I. (2006). Enhancing the performance of direct seeded fine rice by seed priming. *Plant Production Science, 9(4), 446-456.*
9. Farooq, M., Siddique, K. H., Rehman, H., Aziz, T., Lee, D. J., & Washid, A. (2011). Rice direct seeding: experiences, challenges and opportunities. *Soil and Tillage Research, 111 (2), 87-98.*
10. Gao, X., Zou, C., Fan, X., Zhang, F., & Hoffland, E. (2006). From flooded to aerobic conditions in rice cultivation: consequences for zinc uptake. *Plant and Soil*, *280*(1-2), 41-47.
11. Gill, J. S., Walia, S. S., & Gill, R. S. (2014). Direct seeded rice: An alternative rice establishment technique in north-west India–A. *International Journal*, *2*(3), 375-386.
12. Horie, T., Lubis, I., Takai, T., Ohsumi, A., Kuwasaki, K., Katsura, K., & Nii, A. (2003). Physiological traits associated with high yield potential in rice.*Rice Science: Innovations and Impacts for Livelihood. IRRI, Manila*, 117-146.
13. Islam, R., Mukherjee, A., & Hossin, M. (2012). Effect of osmopriming on rice seed germination and seedling growth. *Journal of the Bangladesh Agricultural University*, *10*(1), 15-20.
14. 14. Jie L, Gong She L, Dong Mei O, Fang Fang L, En Hua W. 2002. Effect of PEG on germination and active oxygen metabolism in wildrye (Leymu.7 chinensis) seeds. ActaPrataculturaeSinica11 59-64.
15. Kakraliya SK, et al. Performance of portfolios of climate smart agriculture practices in a rice–wheat system of western Indo-Gangetic plains. Agric. Water Manag. 2018;202:122-133.
16. Krishi Diary, 2022. Agriculture Information and Training Center, Ministry of Agriculture and Livestock Development, Harihar Bhawan Lalitpur. (www.aitc.gov.np).
17. Mohanty, S. (2015). Trends in global rice consumption. *Rice Today*, *12*(1), 44-45.

18. Mohapatra, P. K., & Mohapatra, R. (2005). Sink-source relationship and yield potential of rice: effect of ethylene on grain filling of late-flowering spikelets.*Rice is life: scientific perspective for the 21st century. International Rice Research Institute, Philippines*, 120-124.
19. Murchie, E. H., Yang, J., Hubbart, S., Horton, P., & Peng, S. (2002). Are there associations between grain-filling rate and photosynthesis in the flag leaves of field-grown rice?. *Journal of Experimental Botany*, *53*(378), 2217-2224.
20. Ntanos, D. A., &Koutroubas, S. D. (2002). Dry matter and N accumulation and translocation for Indica and Japonica rice under Mediterranean conditions. *Field Crops Research*, *74*(1), 93-101.
21. Olugbemi, T. S., Mutayoba, S. K., &Lekule, F. P. (2010). Effect of Moringaoleifera inclusion in Cassava based diets to broiler chickens. *J. poul. Sci.* 9: 363-367.
22. Shrirame, M. D., & Muley, D. M. (2003). Variability and correlation studies in rice. *Indian J. Soils Crops*, 131: 165-167.
23. Takhti, S., & Shekafandeh, A. (2012). Effect of different seed priming on germination rate and seedling growth of Ziziphus Spina-Christi. *Advances in Environmental Biology*, *6*(1), 159-164.
24. Yang, J., Zhang, J., Wang, Z., Liu, K., & Wang, P. (2006). Post-anthesis development of inferior and superior spikelets in rice in relation to abscisic acid and ethylene. *Journal of Experimental Botany*, *57*(1), 149-160.