Journal of Nepal Agricultural Research Council
Vol. 6: 101-114, March 2020
ISSN: 2392-4535 (Print), 2392-4543 (Online)
DOI: https://doi.org/10.3126/jnarc.v6i0.28121

Nutrient Management for Higher Productivity of Swarna Sub1 under Flash Floods Areas

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Received 13 Sept 2017, Revised 27 July 2019, Accepted 2 Nov 2019, Published 17 March 2020
Scientific Editors: Jiban Shrestha, Subash Subedi

The authors declare that there is no conflict of interest.

ABSTRACT

Two field experiments were conducted at Regional Agricultural Research Station, Tarahara, Nepal during 2012 and 2013 to determine the effect of agronomic management on growth and yield of Swarna Sub1 under flash floods. The first experiment was laid out in a split plot design with three replications; and four different nutrient combinations at nursery as main plots and three age groups of rice seedlings as sub plots. The second experiment was laid out in a randomized complete block design and replicated thrice; with three post flood nutrient doses at six and 12 days after de-submergence (dad). The experiments were complete submerged at 10 days after transplanting for 12 days. The survival percentage, at 21 dad, was significantly higher in plots planted with 35 (90.25%) and 40 (91.58%) days-old seedlings compared to 30 days-old seedlings (81.75%). Plots with 35 days-old seedlings produced 5.15 t ha^{-1} with advantage of 18.83% over 30 days-old seedlings. Plots with 100-50-50 kg N-P_2O_5-K_2O/ha at nursery recorded the highest grain filling of 79.41% and grain yield of 5.068 t/ha with more benefit. Post flood application of 20-20 N-K_20 kg/ha at 6 dad resulted in higher plant survival and taller plants, leading to significantly higher grain yield of 5.183 t/ha and straw yield of 5.315 t/ha. Hence, 35-40 days old seedlings raised with 100-50-50 kg N-P_2O_5-K_2O /ha in nursery and the additional application of20-20 kg N-K_2O /ha at 6 dad improved plant survival and enhanced yield of Swarna Sub1 under flash flood conditions. The practice has prospects of saving crop loss with getting rice yield above national average yield leading to enhanced food security in the flood prone areas of Nepal.

Keywords: Flash floods, nutrient management, seedling age, Swarna Sub1, yield

सारांश

अचानक बाढी आएको अवस्थामा वाली व्यवस्थापनबाट स्वर्ण सब १ धानको बृद्धि र उत्पादकत्वमा पर्ने असरहरुको अध्ययन गर्न यस क्षेत्रीय कृषि अनुसन्धान केन्द्र, तरहरा, सुनसरीमा सन् २०१२ र २०१३ सालमा २ वटा परिक्षण संचालन गरिएको थियो । पहिलो परिक्षण स्प्लीट प्लट डिजाइनमा तीन पटक दोहोर्याई, साथै मुख्य प्लटमा नर्सरी ब्याडमा मलका ४ वटा विभिन्न मात्राहरु र सब प्लटमा ३ वटा उमेरका वेर्ना राखि संचालन गरिएको थियो । दोश्रो परिक्षणलाई पनि ३ पटक दोहोर्याई रेनडमाइज्ड कमप्लीट ब्लक डिजाइनमा संचालन गरिएको थियो । जसमा ३ वटा विभिन्न मलको मात्रा पानी हटाइएको ६ र १२ दिनपछि हालिएको थियो । यी दुवै परिक्षणहरुलाई रोपाई गरेको १० दिन पछि १२ दिनसम्म पानीमा डुबाइएको थियो । उक्त परिक्षणहरुबाट पानी हटाइएको २१ दिन पछि ३५ दिनको वेर्नामा ९०.२५% र ४० दिनको वेर्नामा ९१.५८% वाच्न सक्ने क्षमता प्रतिशत पाइयो । साथै ३५ दिनको वेर्नाको उत्पादकत्व ५.१५ टन/हेक्टर अर्थात १८.८३% ले ३० दिनको वेर्नाभन्दा बढी पाइयो । नर्सरी ब्याडमा नाइट्रोजन, फस्फोरस र पोटासियम मलको मात्रा १००:५०:५० के.जी/हेक्टरको दरले सबैभन्दा बढी पुष्ट दाना प्रतिशत (७९.४१%) र उत्पादकत्व (५.०६८ टन/हेक्टर) दिएको पाइयो । दोश्रो परिक्षणमा पानी हटाइएको ६ दिन पछि नाइट्रोजन र पोटासियम मलको मात्रा २०:२० के.जी/हेक्टरको दरले प्रयोगले सबैभन्दा धेरै वाली बाच्न सफल भएकोले उत्पादकत्व पनि ५.१८३ टन/हेक्टर सम्म पुगेको पाइयो ।

तसर्थ, एक्कासी बाढी आएको अवस्थामा नाइट्रोजन, फस्फोरस र पाटासियम मलको मात्रा १००:५०:५० के.जी/हेक्टरको दरले प्रयोग गरेर ३५-४० दिनको वेर्ना नर्सरी ब्याडमा तयार गरिएको र पानी हटाइएको ६ दिन पछि थप नाइट्रोजन र पोटासियम मलको मात्रा २०:२० के.जी/हेक्टरको दरले प्रयोग गर्दा स्वर्ण सब १ धानको सुधारात्मक बृद्धि र परिस्कृत उत्पादकत्व भएको पाइयो । यो अभ्यासले बाली नोक्सानी हुनबाट जोगाई राष्ट्रिय उत्पादकत्वभन्दा बढी उत्पादन दिने हुनाले नेपालको आकस्मिक बाढी ग्रस्त क्षेत्रमा खाद्यान्न सुरक्षामा योगदान पुऱ्याउँछ ।

INTRODUCTION

Rice (*Oryza sativa*, n=12) stands the first position in Nepal in terms of area and production, covering 1.55 million hectares (ha) and producing 5.23 million metric tons with the productivity of 3.37 t/ha in Nepal (MoALD 2018). The growth during 2000 to 2012 for rice has been modest as the increase was 2.5% in rice yield, 0.8% in area and 3.6% in production. The Gross Domestic Product (GDP) and Agriculture Gross Domestic Product (AGDP) growths declined to 3.5 and 1.6% from 4.5 and 3.5%, respectively, in 2013 due to drop in rice (11.3%), maize (8%) and millet (2%) production, caused by drought and erratic rains (MoAD 2013). There are indications that rice production will be further adversely affected by the water stresses, caused by the changing climate.

Current climate risks (IRRI 2007) suggests that to continue to meet the demand for rice in Asia, yields will have to be doubled over the next 50 years, but changes in rainfall pattern have been making rice crops less productive. Nepal is the fourth most climate vulnerable country in the world for its extraordinary geography and is highly exposed to a range of water related hazards such as flood, drought, and landslides (World Bank 2013). Nepal has extraordinary geography, a largely resource-poor population and weak institutional capacity to manage the climate challenges.

It is reported that flash floods and submergence adversely affect at least 16% of the rice area globally (Sarkar et al 2006). In Nepal, rice is cultivated in irrigated, rainfed, upland and lowland conditions. Irrigated rice accounts for 56% of the total rice area in Nepal (Tripathi et al 2019). However, area suffering from flash floods is less than area suffering with drought. Flash flood normally occurs during July and August after the heavy monsoon rain. In flood-prone ecosystem, it reduces plant stand, affects crops during transplanting to tillering stage and sometimes during early seedling stage (Bailey-Serres et al 2010). If a flood occurs in the beginning of the season, farmers face the shortage of seedling for transplanting and transplanting is often delayed. When it occurs after transplanting and plants remain submerged for more than a week, all the plants are damaged. The flood also affects vegetative growth, tillering ability and photosynthesis process of rice plants (Bailey-Serres et al 2010, Tamang and Fukao 2015). The farmers are particularly at risk with these unexpected weather shocks resulting in crop loss. Further, crop loss limits the expected benefit from investments in agricultural inputs such as fertilizer. In response, farmers invest less in fertilizer inputs if their fields are prone to flooding or to drought. Such risk-management measures result in lower crop yields even during seasons of normal rainfall. Further, available modern rice varieties are not suitable for these conditions and farmers use to grow their local landraces with a minimal yield potentiality.

After the considerable efforts in collaboration with International Rice Research Institute (IRRI), Sub1, a flood tolerant variety was released in 2011 in Nepal. It regenerates, if field is de-submerged, after complete submergence even for 14-16 days (Fukao et al 2006, Ismail et al 2013). This high yielding Sub1 rice variety can help farmers to replace poor yielding varieties in the flood prone areas. The areas with adverse impact of floods in standing rice crop, farmers need proper management options that boost the productivity. Damage from submergence is most likely when rice plants are younger, and the damage may be higher under imbalanced fertilization condition. Similarly, applying excess nitrogen (N) in the seedbed may be harmful because such seedlings are more vulnerable to submergence. Therefore, improving seedling health in nursery through balanced nutrient management may lead to better crop establishment (Sarkar et al 2006). Proper seedbed nutrient management can contribute considerably to maximize submergence tolerance and grain yield of rice crop in main field (Ravi Kumar et al 2012). Late transplanting of older, healthy and taller seedlings may be another promising option although too old seedlings are less productive. Post-submergence nutrient management contribute for increasing productivity in flood-prone areas (Haefele et al 2012). In particular, nitrogen has been reported to be the only possible limiting nutrient for rice production in flood-prone areas (Panaullah et al 2001). Similarly, potassium application after de-submergence is also considered beneficial especially in submergence prone-areas (Gautam et al 2016b) as it has important role in mitigating submergence-induced stress in rice (Dwivedi et al 2017). Therefore, additional potassium along with N was applied to observe its effect on post submergence recovery. Hence, based on the above scenario, series of experiments were conducted to determine suitable nutrient management options in nursery and post flood nutrient application on Swarna Sub1under submergence conditions. The study also aimed at identifying suitable age of Swarna Sub1 seedlings for transplanting for enhanced productivity.

MATERIALS AND METHODS

Experimental Site

The two on-station field experiments were conducted under a humid, subtropical environment at the Regional Agricultural Research Station (RARS), Tarahara, Sunsari, Nepal during the wet seasons of 2012 and 2013. It is located at 26º42'16.85" North latitude and 87º16'38.43" East longitudes. Its elevation is 136 meters above sea level. It is a tropical zone with warm climatic conditions. Majority of the area is under irrigation. In the year 2012, the monsoon was active from May to September with the highest rainfall in June (282.3 mm) and May (273.4 mm). During 2013, highest rainfall was received in July (667 mm) comparatively higher than previous year till the end of October (**Figure** 1). Amount of rainfall received was in increasing trend over the past two years. During 2012 and 2013, maximum temperature was recorded from March to November and varied from 29 to 35^{0} C (**Figure** 1).

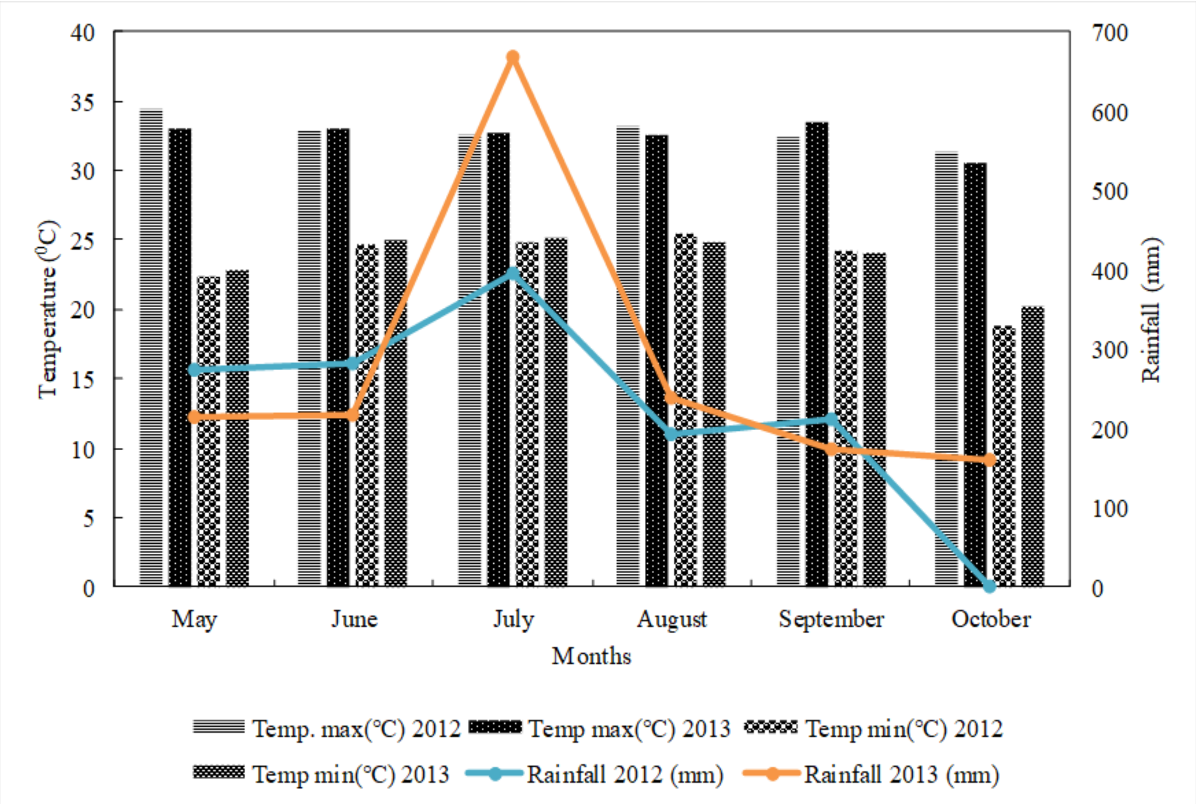


Figure 1. Monthly weather during wet season 2012 and 2013 experimentation period at Regional Agricultural Research Station Tarahara, Sunsari, Nepal.

Experimental Design and Management

Nursery nutrient management: The experiment was conducted in an outdoor natural/normal pond after well puddling and leveling with required amount of moisture in the soil. The pond was managed in a normal environment condition with a proper drainage canal at one side. The main field experiment was laid out in a split-plot design and replicated thrice using four treatments of nursery nutrient management (N); N1: 50-00-00 kg N-P_2O_5-K_2O/ha (farmers practice), N2: 75-50-50 kg N-P_2O_5-K_2O/ha, N3: 100-50-50 kg N-P_2O_5-K_2O/ha, N4: 125-50-50 kg N-P_2O_5-K_2O/ha in main plot and seedlings of different age at transplanting (A);A1: 30-days (d) old, A2: 35-d old and A3: 40-d old in sub-plots (**Table** 1). The seed of Swarna Sub1 rice variety was sown in wet seedbed outside the pond at 5 days interval to get three age groups of seedlings for transplanting. The recommended amount of nursery fertilizers was applied as basal.

The individual plot size was 4mx1.5m in the main field. Seeding was done by using pre-germinated seeds. Two to three seedlings/hill were transplanted with spacing of 25cmx20cm in the pond. Gaps were filled to ensure 100% plant population before submergence. The individual plots in the main field were fertilized with the common dose of nutrients 100-30-30 kg N-P_2O_5-K_2O/ha. One third, and the full dose of phosphorous and potash were applied as basal along with 24 kg/ha zinc before transplanting. The remaining 2/3rd dose of nitrogen were fertilized in two equal splits at active tillering and at panicle initiation stages.

Table 1. Details of field experiments conducted at Regional Agricultural Research Station Tarahara, Sunsari, Nepal during wet season of 2012 and 2013

Experiment and design	Treatments Details	
Nursery nutrient management (Split-plot design)	Main plot: Nutrient management (N)	N1: 50-00-00; N2: 75-50-50; N3: 100-50-50; N4: 125-50-50 kg N-P_2O_5-K_2O ha^{-1}; 25 Kg N applied through 5t FYM /ha in all plots
	Sub plot: Seedling age (A)	A1: 30-d†; A2: 35-d; A3: 40-d
Post flood nutrient management (RCBD design)	Additional post flood nitrogen and potassium application (D)	D1: 00-00 (no additional fertilizer); D2: 20-00 (at 5-6 dad); D3: 20-10 (at 5-6 dad); D4: 20-20 (at 5-6 dad); D5: 20-00 kg /ha (at 10-12 dad); D6: 20-10 (at 10-12 dad); D7: 20-20 kg N-K_2O ha^{-1}(at 10-12 dad)

†d: days; †dad: days after de-submergence

Post-Flood Nutrient Management (kg N-K_2O/ha): The seven different post flood nutrient treatment combinations were used after de-submergence (D);D1: 00-00 (no additional fertilizer); D2: 20-00 (at 5-6 dad); D3: 20-10 (at 5-6 dad); D4: 20-20 (at 5-6 dad); D5: 20-00 (at 10-12 dad); D6: 20-10 (at 10-12 dad); D7: 20-20 kg N-K_2O/ha (at 10-12 dad).

The seedbed was prepared in normal field following recommended farmer's practice of 50-00-00 kg N-P_2O_5-K_2O/ha. The entire amount of nursery fertilizer was applied as basal. The experiment was laid out in a randomized complete block design and replicated thrice. Seeding was done by using pre-germinated seeds. Thirty-five days old seedlings were transplanted in the main field with the spacing of 20cm x15cm and 2-3 seedlings per hill. Fertilizer was applied at the rate of 100-30-30 kg N-P_2O_5-K_2O/ha in main field with the similar schedule of nutrient application as for the main field in nursery management.

The additional doses of nitrogen and potash were applied after de-submergence as per treatments combination and schedule in addition to the recommended dose of fertilizers. These extra doses of nitrogen and potash were applied as per treatment combinations when 40-45% (5-6 dad) and 80-90% (10-12 dad) surviving plants started showing at least emergence of one new green leaf after de-submergence.

Imposition of Complete Submergence

In both the experiments, the transplanted rice plants were completely submerged with the water depth of 1m, after 10-days of transplanting. Filling of water in the ponds was started from noon to give plants enough time to accumulate carbohydrates through photosynthesis in the morning. A desired water depth of 1m was maintained by adding water regularly in the ponds. The submergence was terminated after 12th day of submergence. Algal growth was minimized by removing algae from the water surface daily. Survival was then recorded 21 days after de-submergence by counting the surviving hills.

Data Collection and Statistical Analysis

Average plant height was measured from the base of the stem up to the longest panicle tip in randomly selected 12 hills in each plot. To determine the effective tillers/meter square, only the panicle bearing tillers were counted from 12 sample hills and its average was expressed in tillers/meter square. Days to flowering were determined when 50% of the hills in each plot had reached anthesis. Survival was recorded 21 days after de-submergence by counting the surviving hills. Panicles were hand-threshed and the filled and unfilled grains were separated. Total spikelets/meter square was calculated by adding the numbers of filled, half-filled and empty spikelets/meter square, and percent grain filling was also determined.

Grain and straw yields were determined from the harvested area of 1m^2 marked in the middle of each sub-plot. Grain samples were harvested, dried and adjusted to a moisture content of 12% for determining thousand grain weight and yield. The straw was sun dried, weighed and expressed in t/ha. Harvest Index was determined by dividing grain yield to biological yield.

The data of two individual years were statistically analyzed using MSTAT-C and compared among the different treatments. The combined/pooled analysis of the two years was also performed to understand the consistency of the use of different nutrient management and age groups of seedlings. Treatment means were compared using the least significant difference (LSD) tests and compared at p≤ **0.**05 level of significance (Shrestha 2019).

Economic Analysis

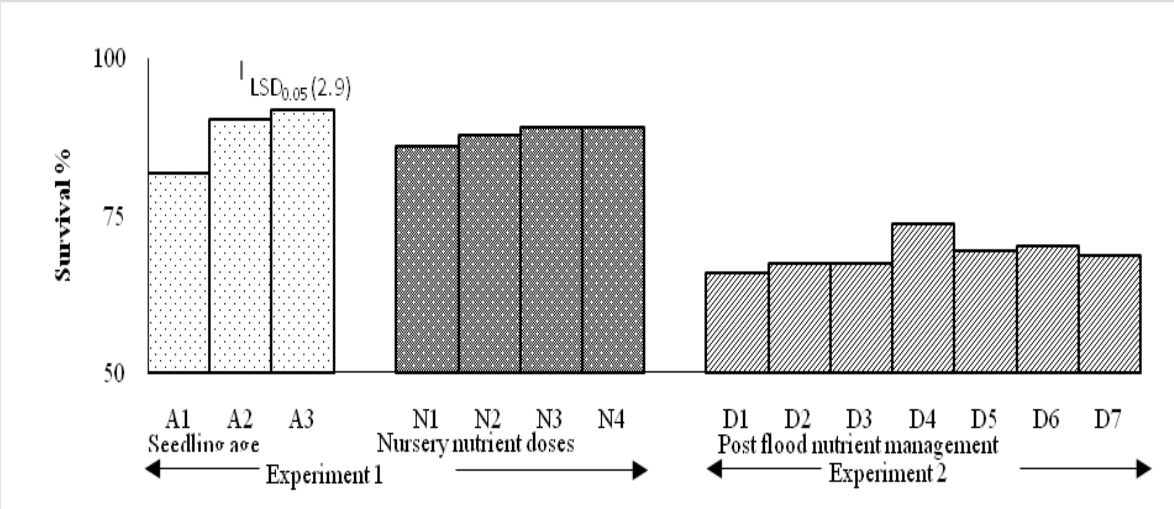
Economic analysis was also carried out to validate profitability of the nutrient management option(s). Treatments were evaluated based on total variable cost, gross return, gross margin, and benefit-cost ratio (BCR). Total variable cost was calculated by taking into account the costs of inputs (seed, fertilizer and pesticides); costs of human labor for land preparation, irrigation, fertilizer and pesticide application, harvesting, bundling, carrying and threshing; and costs of using a power tiller for land preparation and an irrigation pump for irrigation. Gross return was calculated by multiplying the amount of produce (grain and straw) by its corresponding price at harvest. The gross margin and BCR were computed.

The economic analysis was conducted by taking into account the prevailing market price of inputs, labors and produce during the year 2012-13 in Nepalese Rupees and converting it to US dollar at the rate of NPR.100 per US $.

RESULTS

Nursery Nutrient Management

Effects on growth and yield parameters: The pooled data of the consecutive years 2012 and 2013 indicated that the seedling age in main field had significant effect on survival after de-submergence, plant height, days to flowering, tiller number per m^2 at maturity, grain filling percentage, straw yield and grain yield except thousand grain weight (**Figure** 2; **Table** 2, 3).



A1: 30-d; A2: 35-d; A3: 40-d; N1: 50-00-00; N2: 75-50-50; N3: 100-50-50; N4: 125-50-50 kg N-P_2O_5-K_2O per ha; 25 Kg N applied through 5 t FYM /ha in all plots; D1: 00-00 (no additional fertilizer); D2: 20-00 (at 5-6 dad, days after de-submergence); D3: 20-10 (at 5-6 dad); D4: 20-20 (at 5-6 dad); D5: 20-00 kg/ha (at 10-12 dad); D6: 20-10 (at 10-12 dad); D7: 20-20 kg N-K_2O /ha (at 10-12 dad). Vertical bars above the line represent the corresponding $LSD_{0.05}$ values.

Figure 2. Survival (%) as influenced by seedling age at transplanting and different nursery nutrient doses (Experiment 1) and post flood additional N and K_2O application (Experiment 2).

Among the different aged seedlings, survival percentage was higher in plots planted with 35-d and 40-d old seedlings by 9.41% and 10.73% respectively over that of 30-d old seedlings (Figure 2). Taller plants were observed in 40-d old seedlings (76.51 cm) and at par with 35-d old seedlings but significantly taller than 30-d old seedlings by 4.34%. Tiller number/square meter, straw yield, grain filling percent and grain yield were recorded higher in plots planted with 35-d old seedlings (Table 2 and 3). Grain yield in plots planted with 35-d old seedling was significantly superior by 18.83% and 4.66% to those of 30- and 40-d old seedlings respectively (Table 3). Straw yield and grain filling% were similar between the plots planted with 35-d and 40-d old seedling (Table 2 and 3).

Table 2. Growth parameters and yield attributes influenced by seedlings age at transplanting and nursery nutrient management at Regional Agricultural Research Station, Tarahara, Sunsari, Nepal during wet season 2012 and 2013

Treatments	Plant height at maturity (cm)	Tillers per square meter at maturity	Grains /panicle	Grain Filling (%)	Thousand Grain Weight (g)
Seedling age					
30-d	†73.19b	303.8b	123.4b	74.03b	19.35
35-d	75.92a	323.8a	132.9a	79.72a	19.83
40-d	76.51a	314.2ab	133.7a	78.48ab	19.83
LSD(0.05)	1.539	18.89	8.477	2.594	ns
Nursery nutrient management (kg N-P_2O_5-K_2O /ha; 25 Kg N applied through 5 t FYM /ha in all plots)					
50-00-00	74.00b	299.4b	127.3	75.71b	19.39
75-50-50	75.21ab	320.6a	130.0	78.26ab	19.67
100-50-50	74.81ab	324.4a	133.8	79.41a	19.86
125-50-50	76.82a	311.1ab	128.9	76.26b	19.78
LSD (0.05)	2.60	15.45	ns	2.582	ns
CV (%)	3.48	10.23	11.09	5.7	4.34

**ns: non-significant †Means of 12 replications in case of seedling age and of 9 replications in case of fertilizer dose, Means in column with same superscript is not significantly differed by LSD (P≤0.05).*

The nutrient management levels had significant influence on plant height, days to flowering and maturity, tiller number, grain filling percentage, straw yield, and grain yield (**Table** 2 and 3). Plants were taller with application of 125-50-50 kg N-P_2O_5-K_2O/ha whereas shorter by 3.67% with 50-0-0 kg N-P_2O_5-K_2O/ha (**Table** 2). Delayed maturity by 5-6 days was recorded with the application of 75-50-50kg N-P_2O_5-K_2O/ha and was statistically at par with 100-50-50 kg N-P_2O_5-K_2O/ha (4 days) and 50-0-0kg N-P_2O_5-K_2O/ha, but earlier maturity (134.3 days) was obtained with application of 125-50-50kg N-P_2O_5-K_2O/ha (**Table** 3). Application of nutrient dose of 100-50-50 kg N-P_2O_5-K_2O/ha was more productive for grain filling%, straw yield and grain yield (**Table** 3). There was an increase by 4.55%, 13.71% and 12.34% in grain filling%, grain yield and straw yield respectively by 100-50-50 kg N-P_2O_5-K_2O/ha over 50-0-0 kg N-P_2O_5-K_2O/ha.

Table 3. Phenology, grain and straw yield influenced by seedlings age at transplanting and nursery nutrient management at Regional Agricultural Research Station Tarahara, Sunsari, Nepal during wet season 2012 and 2013

Treatments	Days to flowering	Days to maturity	Grain yield (t/ha)	Straw yield (t/ha)	HI
Seedling age					
30-d	† 102.29a	139.7 a	4.18 c	4.73 b	0.469
35-d	101.67b	137.6 ab	5.15 a	5.49 a	0.484
40-d	99.75c	137.4 b	4.91 b	5.42 a	0.475
LSD(0.05)	0.57	2.17	0.1923	0.2176	0.08
Nursery nutrient management (kg N-P_2O_5-K_2O /ha; 25 Kg N applied through 5 t FYM /ha in all plots)					
50-00-00	102.50a	139.9 a	4.373 c	4.837 b	0.475
75-50-50	101.78a	140.1 a	4.639 ab	5.063 b	0.477
100-50-50	101.72a	138.5 a	5.068 a	5.518 a	0.478
125-50-50	98.94b	134.3 b	4.906 ab	5.439 a	0.474
LSD(0.05)	1.31	3.166	0.2785	0.308	ns
CV (%)	0.96	2.68	6.90	7.10	2.61

[*]ns: non-significant †Means of 12 replications in case of seedling age and of 9 replications in case of fertilizer dose, Means in column with same superscript is not significantly differed by LSD (P≤0.05).

Interaction effects on phenology, yield attributes and grain yield: The interaction effect of seedling age and nitrogen management dose was non-significant on all the growth, yield and its attributing characters.

Economic analyses: The gross return of 1397.52 US$ from transplanting of 35-d old seedling was significantly higher as compared to other age group of seedling, mainly because of the higher grain and straw yields.

Table 4. Economic analyses (US$/ha) of seedling age at transplanting and nursery nutrient management practices at Regional Agricultural Research Station Tarahara, Sunsari, Nepal during wet season 2012 and 2013

Treatments	Total Variable Cost	Gross Return	Gross Margin	BCR
Seedling age				
30-d	60775.00	†1139.65c	531.90.83c	1.87 c
35-d	60775.00	1397.52 a	789.77.50a	2.30 a
40-d	60775.00	1335.47 b	727.72.50b	2.20 b
Nursery nutrient management (kg N-P_2O_5-K_2O/ha; 25 Kg N applied through 5 t FYM/ha in all plots)				
50-00-00	56650.00	1190.07c	623.57.78b	2.10b
75-50-50	61525.00	1260.98 b	645.73.89b	2.05b
100-50-50	62150.00	1377.31a	755.81.11a	2.22a
125-50-50	62775.00	1335.16a	707.41.67a	2.13ab

[*]ns: non-significant †Means of 12 replications in case of seedling age and of 9 replications in case of fertilizer dose,Means in column with same superscript is not significantly differed by LSD (P≤0.05).

Among the nutrient management treatments, the highest gross return of 1377.31US$ was obtained with 100-50-50 kg N-P_2O_5-K_2O/ha followed by 125-50-50 kg N-P_2O_5-K_2O/ha which was significantly higher than 50-00-00 kg N-P_2O_5-K_2O/ha and 75-50-50 kg N-P_2O_5-K_2O/ha. The benefit cost ratio (BCR) did not vary significantly in different nutrient management options but there was a significant increasing trend in BCR due to seedling age. Highest BCR (2.3) and gross margin (789.77 US $) was recorded in plots planted with 35 days old seedling. BCR in 30 days old seedling was lower by 18.69% and 15% than 35 and 40 days old seedling respectively. Similarly, the gross margin was obtained highest (755.81 US $) from plots applied with 100-50-50 kg N-P_2O_5-K_2O/ha which was at par with 125-50-50 kg N-P_2O_5-K_2O/ha. The gross margin and gross return in the treatment 100-50-50 kg N-P_2O_5-K_2O/ha was higher by 17.49% and 13.59% respectively than 50-00-00 kg N-P_2O_5-K_2O/ha. The economic analysis shows that the gross margin, gross return and BCR reach to a threshold point with the application of 100-50-50 kg N-P_2O_5-K_2O/ha and after which they slowly decline.

Fertilizer management for quick recovery after de-submergence

Effects on growth and yield parameters: Additional application of 20-20 kg N-K_20Oha at 5-6 days after de-submergence (dad) recorded maximum survival rate (**Figure** 2), plant height, tillers/square meter, grain filling percentage, grains/panicle, grain and straw yield (**Table** 5, 6). Plant height at maturity ranged from 67.63 to 73.40 cm, with highest by 7.86% when applied 20-20 kg N-P_2O_5-K_2O/ha at 5-6 dad as compared to treatment without any additional fertilizer application. Days to maturity also varied significantly, duration was longer (135.5 days) when applied with 20-20 kg N-K_2O/ha at 10-12 dad, significantly different to all other treatments except when 20-10kg N-K_2O/ha was applied at 5-6 dad (134.8 days). Maturity duration was earlier with 20-00kg N-K_2O/ha nutrient at 5-6 dad. Maximum number of tillers/square meter was recorded in 20-20 kg N-K_2O/ha at 5-6 dad by 24.48% over 20-00 kg N-K_2O/ha at 5-6 dad (**Table** 5). Moreover, highest grain filling percentage of 81.28% was obtained with 20-20 kg N-K_2O/ha (D4) at 5-6 dad.

Table 5. Growth parameters and yield attributes influenced by different post flood nutrient doses (kg N-K_2O/ha) at Regional Agricultural Research Station Tarahara, Sunsari, Nepal during wet season 2012 and 2013

Treatments	Plant height at maturity(cm)	Tillers per square meter at maturity	Grain filling %	Grains /panicle	1000 grain weight (g)
Additional post flood nutrient dose (kg N-K_2O ha^{-1})					
00-00	68.27	†216.7 c	71.80	159.8 b	19.33
20-00 at 5-6 dad†	69.02	253.6 bc	75.72	182.9 b	18.83
20-10 at 5-6 dad	70.60	300.1 ab	77.83	187.6 b	19.75
20-20 at 5-6 dad	73.40	335.8 a	81.28	226.9 a	19.00
20-00 at 10-12 dad	72.13	260.0 bc	70.50	160.5 b	19.17
20-10 at 10-12 dad	67.63	292.1 ab	73.82	167.3 b	18.33
20-20 at 10-12 dad	70.25	314.2 ab	77.40	186.5 b	17.92
$LSD_{0.05}$	3.56	57.58	2.94	25.62	ns*
CV (%)	4.26	17.15	3.27	11.84	5.17

†*dad: days after de-submergence;* **ns: non-significant†Means of 3 replications, Means in column with same superscript are not significantly differed by LSD (p≤0.05).*

Table 6. Phenology, grain and straw yield as influenced due to different post flood nutrient doses (kg N-K_2O /ha) at Regional Agricultural Research Station Tarahara, Sunsari, Nepal during wet season 2012 and 2013

Treatments:	Days to maturity	Grain Yield(t/ha)	Straw Yield(t/ha)	HI
00-00	†134.2	4.082 d	4.262 c	0.49
20-00 at 5-6 dad†	132.7	4.350 cd	4.560 bc	0.488
20-10 at 5-6 dad	134.8	4.753 abc	4.907 ab	0.498
20-20 at 5-6 dad	134.5	5.183 a	5.315 a	0.494
20-00 at 10-12 dad	134.3	4.533 bcd	4.825 ab	0.484

Treatments:	Days to maturity	Grain Yield(t/ha)	Straw Yield(t/ha)	HI
20-10 at 10-12 dad	134.5	4.883 ab	5.210 a	0.484
20-20 at 10-12 dad	135.5	4.867 ab	5.122 a	0.487
LSD (0.05)	0.77	0.463	0.499	ns*
CV (%)	0.48	8.33	8.59	2.95

*dad: days after de-submergence; *ns: non-significant; HI: harvest index. †Means of 3 replications, Means in column with same superscript are not significantly differed by LSD (P≤0.05)*

The treatment with the additional application of 20-20 kg N-K_2O/ha at 6 dad resulted in the highest grains/panicle contributing to the higher grain yield. The grain/panicle was higher by 29.57% with the application of 20-20 kg N-K_2O/ha at 5-6 dad as compared to no additional post flood nutrient dose. Grain yield of all treatments ranged from 4.08 to 5.19 t/ha. Significantly higher grain yield was recorded with the application of 20-20 kg N-K_2O/ha at 5-6 dad over 20-10 kg N-K_2O/ha at 10-12 dad and 20-20 kg N-K_2O/ha at 10-12 dad. The additional post flood nutrient dose of 20-20 kg N-K_2O/ha at 5-6 dad increased the rice yield by 21.24% as compared to treatment without any post flood nutrient. Similar result was also recorded with the straw yield (**Table** 6). Regarding the thousand grain weight, additional 20-10 kg N-K_2O/ha applied at 5-6 dad had the highest weight of 19.75 g. The harvest index was statistically non-significant among all the treatments.

Economic Analysis: Among the 6 different additional doses of nitrogen and potash, highest BCR (2.18) and gross margin (759.63 US $) were obtained with additional 20-20 kg N-K_2O per ha applied 5-6 dad of flood water from the main plot. Similarly, gross return was also highest with additional 20-20 kg N-K_2O per ha applied at 6 dad. Thus, there was an increase in BCR by 19.61%, gross margin by 37.45% and gross return by 21.15% with additionalpost flood nutrient dose of 20-20 kg N-K_2O/ha applied 5-6 dad of flood water.

Table 7. Economic analyses (US $/ha) of different post flood nutrient doses (kg N-K_2O/ha) at Regional Agricultural Research Station Tarahara, Sunsari, Nepal during wet season 2012 and 2013

Treatments	Total Variable Cost	Gross Return	Grosss Margin	BCR
Additional post flood nutrient dose (kg N-K2O /ha)				
00-00	63050.00	†1105.6d	475.1520 d	1.754 d
20-00 at 5-6 dad†	63550.00	1178.70cd	543.20 cd	1.855 cd
20-10 at 5-6 dad	63900.00	1286.46abc	647.50 abc	2.013 abc
20-20 at 5-6 dad	64250.00	1402.13a	759.63a	2.182 a
20-00 at 10-12 dad	63550.00	1229.83bcd	594.330bcd	1.935 bcd
20-10 at 10-12 dad	63900.00	1325.03ab	686.030 ab	2.074 ab
20-20 at 10-12 dad	64250.00	1319.10ab	676.60 abc	2.053 abc

*†dad: days after de-submergence; *ns: non-significant; BCR: benefit cost ratio. †Means of 3 replications, Means in column with same superscript is not significantly differed by LSD (P≤0.05)*

DISCUSSION

Effect of seedling age at transplanting for Swarna Sub1 performance

A general delay in flowering occurred after submergence in all treatments as the surviving plants took additional time to recover and resume normal vegetative growth, and to overcome damage caused during and after submergence (**Table** 2). This Sub1 gene introgressed narrowed the delay in flowering caused by submergence, possibly by maintaining healthier plants that could recover and resume growth faster, as Sub1 is known to enhance chlorophyll retention and conserve carbohydrate reserves through reducing underwater leaf and stem elongation (Ella et al 2003, Das et al 2005, Fukao et al 2006). All the above and below ground characteristics of rice plants, before and after transplanting, would vary with seedling age (Himeda 1994, Mishra and Salokhe 2008) and growing environment (Kordon 1974).

The effect of aged seedlings was significantly reflected in the main field with regard to better crop survival after submergence, plant height, tiller no./square meter and grain yield. Seedling age might also be related to survival after submergence. Seedling age of 40 and 35 days produced higher grain yield of 4.91 and 5.15t/ha respectively compared to younger seedling of 30 days. This might be because that older seedlings were more tolerant to complete submergence, because of higher vigour and mature tissues, lower underwater shoot elongation and higher carbohydrate content than younger seedlings (Singh et al 2005, Ram et al 2009). Late transplanting of older and taller seedlings in flooded condition might be a promising option but too old seedlings could be of no advantage. Therefore, with the increase in seedling age, there is slight decrease in yield.

Healthy and vigorous seedlings raised in the nursery, could also help farmer to harvest an additional yield of up to 2 t/ha (Panda et al 1991). Alam et al (2002) also found that 35 days old seedlings performed better regarding the number of tillers/hill, the number of effective tillers /hill, grain yield and straw yield in the main field. The older seedlings recovered faster from the transplanting shock, possibly due to the higher nitrogen content. According to Adhikari et al (2013) older seedlings (40 days) produced taller plants, more productive tillers, more filled grains, and a higher grain and straw yield. Similar result was observed that 40 days old seedlings gave higher number of panicles/square meter (Rashid et al 1990). According to Ram et al (2009) and Singh et al (2005), older seedlings were more tolerant to complete submergence, because of higher vigor and mature tissues, lower underwater shoot elongation and high carbohydrate content than younger seedlings. The results by Bhowmik et al (2014) also show that seedling age of 44 days has the highest grain yield of 5.23 t/ha and straw yield of 7.02 t/ha after submergence stress when compared to younger seedlings of 30 days.

Effect of nursery nutrient management on survival, yield attributes and yield

Rice yields depend on the specific area and season with regard to climate, variety, and crop management practices. Application of nutrient dose of 100-50-50 kg N-P_2O_5-K_2O/ha (N3) recorded higher grain filling % and grain yield. The reduction in yield and yield components with increasing fertilizer dose could be attributed to the degree of nutrient uptake by plants at different levels of fertilizer. Bhowmick et al (2014) revealed that the use of lower seeding density (25 g/square meter), application of balanced doses of 80-40-40 kg N-P_2O_5-K_2O /ha in nursery and transplanting 44 days old seedling significantly improved plant survival, yield attributing traits and grain yield. Swarna Sub1 in Nepal also showed a yield advantage of up to 1 to 3 t/ha depending upon the duration of submergence, and was as good or better than original variety (Singh et al 2013). Balanced application of N-P_2O_5-K_2O in the nursery was also beneficial (Singh 2011, Yadav 2012).

Response of Swarna-Sub1 to post flood nutrient management

Dobermann et al (2000) stated that the availability of N is greater in flooded soil than in aerated soil, but various unique features of flooded soils complicate N management. According to Bhowmick et al (2014), the application of additional nitrogen dose of 20 kg N/ha after de-submergence recorded the increase in crop survival, plant height and number of tillers/square meter, panicle length, and thousand grain weight over 10 kg N/ha, which helped the plant to resume faster growth and crop establishment compared to lower N doses. Highest grain yield of 5.18 t/ha was recorded with the additional dose of 20 kg N/ha which was due to the ability of faster recovery and early tiller formation following post-submergence application. Maximum grain yield under 20-20 kg N-K_2O/ha must be due to higher production of tiller/square meter, grain filling % and grain per panicle. Plant growth and yield might not only depend on carbohydrate production through photosynthesis but also on mineral absorption by the roots and its assimilation (Ram et al 2009). The crop flowered and matured mostly at the same time, irrespective of additional N-dose. Similar results were revealed by Bhowmick et al (2014).

There was a decline in grain yield with the decreased dose and delayed application of additional potassium and nitrogen. The lowest dose might not be enough to meet the crops demand after de-submergence and its additional application delayed after 12 days of de-submergence might also not be the optimum time for crop demand after growth recovery. This might be due to the fact that surviving plants could recover faster and resume their normal vegetative growth, overcoming the damage caused during submergence, when an additional dose of N was applied at 7 dad (Singh et al 2013).

The decline in yield was due to the reduced tiller number, grain per panicle and grain filling percentage with the less amount of fertilizer. Nitrogen promotes the rapid increase in plant height, the number of tillers and increased leaf size, spikelet number per panicle, percentage filled spikelets in each panicle and grain protein content (Dobermann et al 2000). During and after submergence, the rice plants remain in such a stress condition that they lack the ability to uptake the available nutrient from the flooded soil and water. The reason behind this is the poor crop establishment and growth during submergence. Further, additional fertilization of 20-20 kg N-K_2O/ha at 5-6 days after termination of submergence was found to be more promising and the most suitable fertilizer rate and application time for better recovery, crop growth, yield, and yield attributes of Swarna Sub1 in the submergence-prone ecosystem. Dwivedi et al (2017) also found that application of potassium at panicle initiation stage was more beneficial to enhance plant survival, better recovery and yield of rice during complete submergence. This might be because potassium mitigates submergence-induced stress in rice by maintaining survival after de-submergence and physiological activities (chlorophyll and antioxidant activity) to mitigate the adverse effect of submergence. Improved survival by potassium application was because of the maintenance of carbohydrates, chlorophyll and contributing to less lodging and leaf senescence and higher antioxidants (Gautam et al 2016b). Therefore, time of fertilizer application during the post submergence period might be one of the crucial factors for determining the recovery growth which would be very important when crop establishment was completely destroyed by flash flood submergence (Ella et al 2006). However, a small additional amount of N might be applied at any time, preferably at one week after the recession of floods for better re-growth and grain yield (Pandey 2013, Mackill et al 2011). Our findings are in line with Gautam et al (2016a) and Gautam et al (2014) who reported that post-flood nitrogen had higher plant survival due to less lodging, senescence and higher antioxidants. Simple alteration in nutrient application time can open up the ways for enhancing the productivity of submergence rice in flash floods prone areas.

Economic Analysis

In nursery nutrient management, the highest gross return, gross margin and BCR in 35 days old seedling might be due to higher grain and straw yield compared to other age groups of the seedling. Similar is the case when 100-50-50 kg N-P_2O_5-K_2O/ha is applied as the nutrient management option. These economic gains might be due to the improved nursery management and higher grain and straw yield. The study by Sarangi et al (2015) also revealed that the BCR of promising nursery management combination with 50-30-15kg N-P_2O_5-K_2O/ha was around 1.8. Further, in their study, the 40 days old seedling also had BCR of 1.82, gross margin of 524 US$, the gross return of 1165 US$ and cost of cultivation of 643 US$.

In case of post flood nutrient management, significantly higher BCR, gross return and gross margin were resulted for the additional doses of 20-20 kg N-K_2O/ha at 5-6 dad as post flood nutrient. As suggested by Reddy and Reddy (1992) B:C values were more than and equal to 2 are necessary for technology adoption. But Makarim et al (2002) considered BCR above 1.5 to be economically viable for an agriculture environment, especially when the investments are small. Thus, the combination of good nursery management with high yielding, stress tolerant varieties could improve the productivity and income of farmers in flood prone areas.

CONCLUSION

The study showed that the use of proper dose of nutrients in nursery produced healthier and more vigorous seedlings that withstand flash floods thus ensuring faster recovery and growth after de-submergence. To sum up, seedling age groups of 40 and 35 days were better for higher grain yield due to more tolerant to complete submergence and produced more tiller number than younger seedlings. Application of nutrient dose of 100-50-50 kg N-P_2O_5-K_2O/ha in the nursery resulted in highest grain yield in flash flood prone areas. Additional fertilization of 20-20 kg N-K_2O/ha, 5-6 days after termination of submergence produced higher yield with higher economic return. These cost-effective results clearly indicated that yield potential of Sub1 introgressed rice variety, grown in submergence stress condition could be considerably increased by 14-21% by proper and timely post flood nutrient and nursery management. However, the practice needs to be further validated in different farmers' field condition.

ACKNOWLEDGEMENTS

This research study was supported by the International Rice Research Institute (IRRI), Los Baňos, Philippines by providing necessary financial and technical support under the European Commission-International Fund for Agricultural Development (EC-IFAD) for developing agronomic management practices of Swarna Sub1. Authors are also thankful to Nepal Agricultural Research Council (NARC), Nepal for providing all the necessary facilities and support and want to acknowledge the hard work of technicians, RARS Tarahara, Sunsari during the entire research period.

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