Chapter 6

Estimation of Genetic Coefficients and Yield Gap Analysis

6.1 Estimation of genetic coefficients

The duration of growth stages in response to temperature and photoperiod varies between species and cultivars, and genetic coefficients are use as model inputs to describe these differences (Hunt and Boote, 1994; Singh *et al*., 2002). The definitions of different genetic coefficient parameters are given in Table 6.1.

Table 6.1: Genetic coefficient parameters for rice.

P1	Time period in growing degree days (base temperature 9^0C) from emergence to end of juvenile phase
P2R	Photoperiod sensitivity (degree day delay per hour increase in daylenght)
P2O	Critical photoperiod or longest daylength (h) at which development occurs at maximum rate. At values than P2O the development rate is slowed (depending on P2R)
P5	Degree days (base temperature 9^0C) from beginning of grain-filling (3-4 days after flowering) to physiological maturity.
G1	Potential spikelet number coefficient as estimated from number of spikelet per g main culm+ spike dry weight at anthsis (#/g).
G2	Single dry grain weight (g) under unlimiting growing conditions.
G3	Tillering coefficient (scalar value) relative to IR64. Higher tillering cultivar will have values greater than 1.
G4	Temperature tolerance coefficient. Usually 1.0 for cultivars grown in normal environment. G4 for japonica type rice grown in warmer environment would be > 1.0. Tropical rice grown in cooler environments or season will have G4< 1.0

(Source: ICASA, 2003).

To estimate genetic coefficients for the Bhutanese rice varieties, experimental data obtained from the varietal Advance Evaluation Trial (AET) conducted by RNR-RC, Bajo for three years (2000-2002) were used. The trials were conducted with same management and fertilizer rate.

As explained in the research methods initial run of the model was conducted by using the genetic coefficient of IR-64 available with DSSAT v4 package for all the varieties and using soil and weather data of RNR-RC, Bajo. After the initial run, genetic coefficients of three varieties, IR-64, BajoMaap2 and BajoKaap2 for all treatments were adjusted individually till the close match was found between the observed and simulated phenomenon. After adjusting the coefficients of three varieties for each treatment, it was used to simulate other treatments, e.g. genetic coefficients of 2000 treatment with 2001 and 2002 treatments and vice versa. Finally, it was found that genetic coefficients of 2001 treatments (Table 6.2) was in good agreement for all treatments with good RMSE and d-stat for growth and yield.

Table 6.2: Adjusted genetic coefficients 2001 treatment.

Genetic Coefficients	Cultivars		
	IR-64	BajoMaap2	BajoKaap2
Juvenile Coefficient (P1), GDD	500	390	500
Photoperiodism Coefficient (P2R), GDD h^{-1}	120	105	125
Grain Filling duration Coefficient (P5), GDD	330	390	340
Critical Photoperiod (P2O), h	12	12	12
Spikelet Number Coefficient (G1)	60	60	60
Single Grain Weight (G2), g	0.025	0.024	0.027
Tillering Coefficient (G3)	1	1	1
Temperature Tolerance Coefficient (G4)	1	1	1

The juvenile phase coefficient (P1), photoperiodic coefficient (P2R), and grain filling duration coefficient (P5) of the cultivars varied from 390 to 500 degree days (^{0}C), 105 to 125 degree-day h^{-1}, and 330 to 390 degree days (^{0}C), respectively. IR-64 and BajoKaap2 had comparatively longer juvenile phase (P1) but slightly less grain filling duration coefficient (P5) than BajoMaap2. The critical photoperiod (P20) is 12 hours for all varieties. Actual grain weights collected from research centre for each variety were used.

6.2 Model validation

To validate the model, the adjusted set of genetic coefficients of all three varieties from the 2001 data set were used to simulate 2000 and 2002 data sets and tested for RMSE and d-statistic. The simulated and observed anthesis days (DAP) for 2000 and 2002 trial agreed quite well with RMSE = 2.65 and d-stat = 0.94 (Table 6.3). Similarly, RMSE and d-stat for physiological maturity was 3.42 and 0.85, respectively. Predicted grain yields in both data set (2000 and 2002) was quite acceptable with observed yields (RMSE = 469.25 kg/ha, d-stat = 0.77). Details of the validation results are presented in Table 6.3 below.

Table 6.3: Observed and Simulated Phenological events and grain yield using adjusted genetic coefficients.

Year	Variety	Anthesis		Phy. maturity		Grain yield	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
		------------------------DAP------------------------				--------Kg/ha--------	
2000	IR-64	85	87	117	123	6,900	7,319
	BajoMaap2	75	76	109	113	6,000	6,020
	BajoKaap2	91	89	121	124	6,400	7,461
2002	IR-64	85	87	118	119	7,000	7,106
	BajoMaap2	80	75	113	111	6,450	6,538
	BajoKaap2	86	88	119	121	7,250	7,273
	RMSE	2.65		3.42		469.25	
	d-stat	0.94		0.85		0.77	

Note: DAP- Days After Planting.

6.3 Yield gap analysis and identify agronomic measures

Yield gap is dynamic and will continue to exist with the development of new technology. All gaps are not practical to close as some are non transferable such as environmental factors. Narrowing rice yield gap will not only increase the productivity and production but also improve the efficiency of land and labor use, reduces production cost, and increases sustainability and food security at household and national level. It can also lead to lower price in the market, thus facilitating access to food for many low income citizens. It is seen as local solution to global problem of food insecurity.

After observing the acceptable capacity of CERES-Rice model to simulate the phenological and yield components, it has been used it to determine potential yield and analyze yield gap between potential yield, experiment plot yield and farmer's field yield of three identified improved varieties in the study area.

6.3.1 IR-64

Simulated potential yield of IR-64 was 9,151 kg/ha (Figure 6.1). Potential yield were simulated without any water and nitrogen stress in a given climate condition. 2002 weather data was used for simulation, which were collected from RNR-RC Bajo. However, soil data was used for simulation were collected from the respective village. The observed experimental yield was 7,000 kg/ha and the average farm yield was 4,813 kg/ha and 4,295 kg/ha for Wangjokha and Omtekha respectively. The average farm yields were derived from crop cuts. Further, average farm yield was also simulated based on the resource use gathered through field survey for both villages. The simulated yields were 4,211 kg/ha and 4,209 kg/ha in Omtekha and Wangjokha respectively. The simulated yield was found to be slightly less than the observed; it could be due to differences in soil nutrient as soil data used for model simulation was colleted six months after the harvest of rice. Further, the weather data use as model inputs were collected from RNR-RC, Bajo as no data were recorded in the studied site.

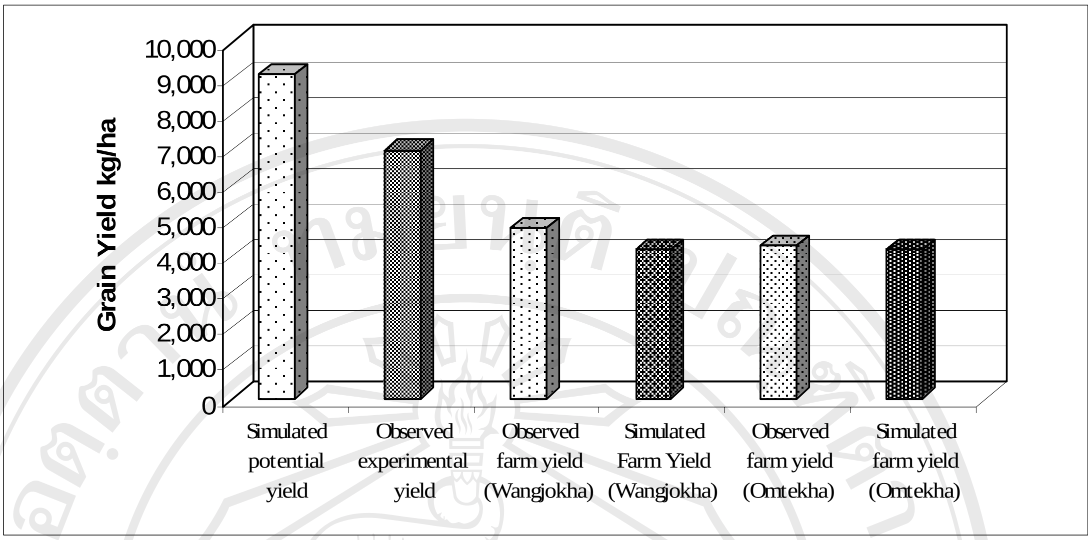

Figure 6.1: Yield gaps of IR-64**.** (Source: Field Survey, 2004 and Simulation).

Analysis indicated that there was huge gap between farmers yield and the simulated potential yield and observed experimental yield (Table 6.4). The gap between farmer yield and potential was calculated to be 47.40% for Wangjokha and 53.06% for Omtekha. Similarly, the gap between farmers yield and observed experimental yield was 31.24% and 38.64% respectively for Wangjokha and Omtekha.

6.3.2 BajoMaap2

Simulated potential yield of BajoMaap2 was 7,865 kg/ha (Figure 6.2).The observed experimental yield was 6,350 kg/ha and the average farm yield was 4,375 kg/ha Wangjokha. Omtekha farmers were not cultivating this variety. As above, the average farm yield of BajoMaap2 was also simulated based on the resource use gathered through field survey and it was found to be 4,212 kg/ha. The simulated yield was found to be slightly less than the observed for this variety too; and it could be due to differences in soil nutrient and the weather data used as model inputs.

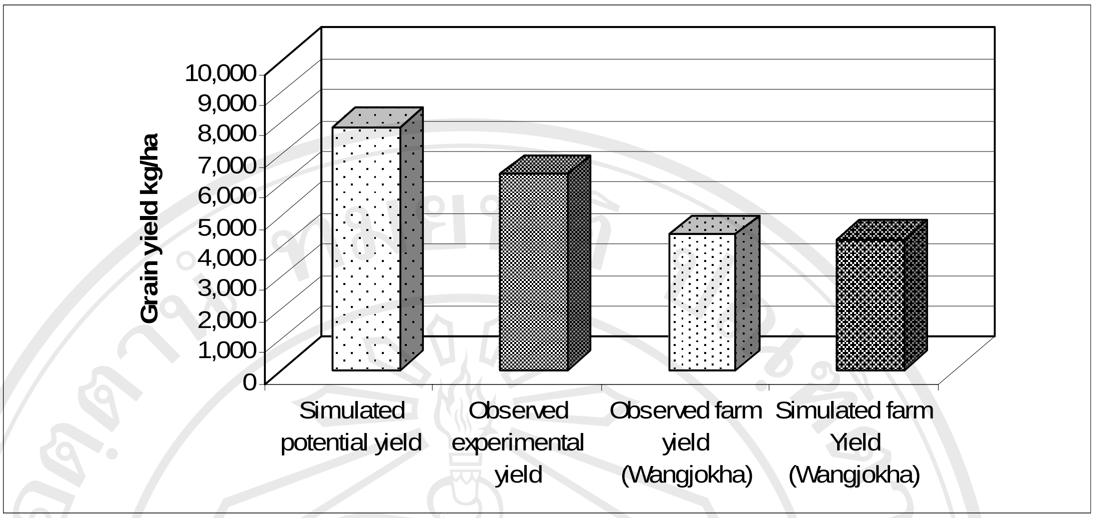

Figure 6.2: Yield gaps of BajoMaap2. (Source: Field Survey, 2004 and Simulation).

Yield gap analysis for this variety also indicated a huge gap between farmers yield and the simulated potential yield and observed experimental yield. (Table 6.4) The gap between farmer yield and potential was calculated to be 44.37%. Similarly, the gap between farmers yield and observed experimental yield was 31.10%.

Table 6.4: Potential, experimental and farm yield and yield gaps in Wangjokha.

Variety	Potential yield	Experimental yield	Average farm yield		Yield gaps as compared to farm yield		
	A	B	C*	D**	(A-B)/A*100	(A-C)/A*100	(A-D)/A*100
	kg/ha				%		
IR-64	9,151	7,000	4,813	4,295	23.50	47.40	53.06
BajoMaap2	7,865	6,350	4,375	Nil	19.26	44.37	Nil
BajoKaap2	9,618	7,250	4,684	Nil	25.11	51.62	Nil

* Average farm yield, Wangjokha farmers.

** Average farm yield, Omtekha farmers

6.3.3 BajoKaap2

Simulated potential yield of BajoKaap2 was 9,681 kg/ha (Figure 6.3) while the observed experimental yield was 7,250 kg/ha. The average farm yield was 4,684 kg/ha Wangjokha. The average farm yield of BajoKaap2 was also simulated based on the resource use gathered through field survey and it was found to be 4,451 kg/ha. In the case also the simulated yield was found to be slightly less than the observed; and it could be due to differences in soil nutrient and the weather data used as model inputs.

While analysis yield gap, it indicated a large gap between farmers yield and the simulated potential yield and observed experimental yield (Table 6.4). The gap between farmer yield and potential was calculated to be 51.62%. Similarly, the gap between farmers yield and observed experimental yield was 35.39%

.

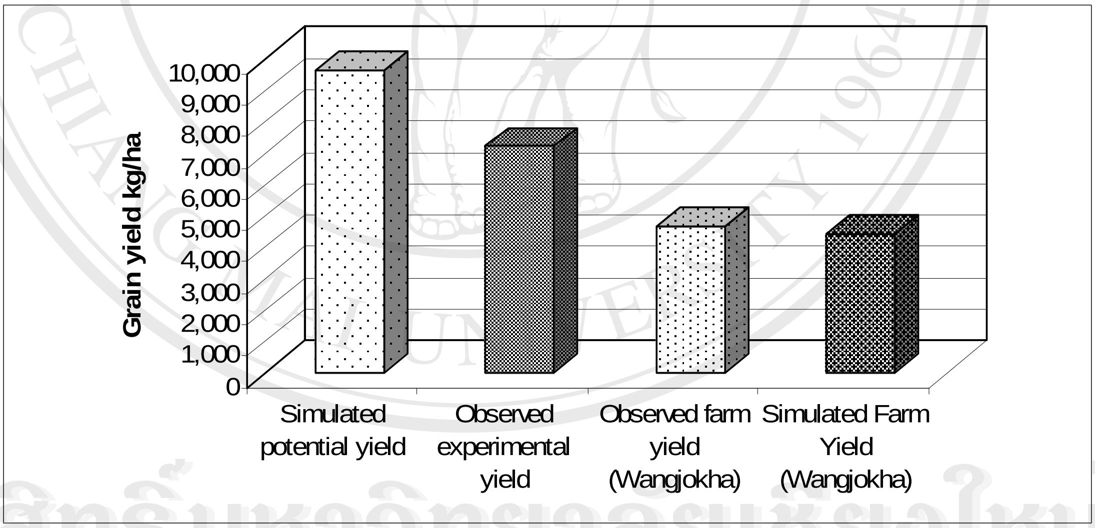

Figure 6.3: Yield Gaps of BajoKaap2. (Source: Field Survey, 2004 and Simulation).

Comparing three varieties, BajoKaap2 has the highest yield potential followed by IR-64 and BajoMaap2, respectively. Comparatively low potential yield of BajoMaap2 could be due to shorter juvenile phase and less photoperiodism coefficient (P2R).

6.4 Simulating affects of nitrogen rate and planting time

The above analysis suggests that there are plenty of scopes to increase farmers yield by improving management practices. Based on the analyzed yield gaps of three varieties and considering the resource use and research's recommendation different hypothetical experiment was designed and simulated using CERES-Rice model to identify factors to narrow the gaps.

Out of many agronomic practices responsible for the existing yield gaps, nitrogen management and planting date were simulated. The impact of nitrogen on rice yield is well recognized and Department of Research and Development Services had also identified improve varieties and optimum fertilizer use as vehicle for higher production (DRDS, 2001). Water, obviously an important resource for rice product is not simulated because of the unpredictable variation in frequency and amount of rainfall for a given location, variation in topography, soil character, crop growing length, different management practices. It is extremely difficult to generalized and find a simple relationship between water requirement and growth (Yoshida, 1981). Considering above facts and finding from the survey and recommendation from research station, six planting date starting from 15th of May to 30th July was simulated in combination with eight different rate of chemical nitrogen fertilizer and 3,000 kg of FYM per hectare. Nitrogen fertilizer was maintained as 0, 20, 40, 60, 80, 100, 120 and 150 kg per hectare. Seedling age was maintained at 40 days old and spacing of 20 cm. Irrigation was applied after every seven days with a flood depth of 60mm as practiced by farmers.

6.4.1 Response to nitrogen rate and planting time by IR-64

In Omtekha, maximum yield was obtained for 30th May planting with the application of 150 N kg/ha (Figure 6.4). However, differences in yield for planting between 30th May and 30th June are negligible, but planting before or after the above date decrease the yield, more so as the nitrogen rate increases. Statistically, increases in nitrogen rate have significant positive effect on yield at less than 0.01 level of significance. But the rate increase was less beyond the application of 100 N kg/ha. Similar trend was noticed for Wangjokha as well. It may be due the fact that simulation was done using the same weather data (Figure 6.5).

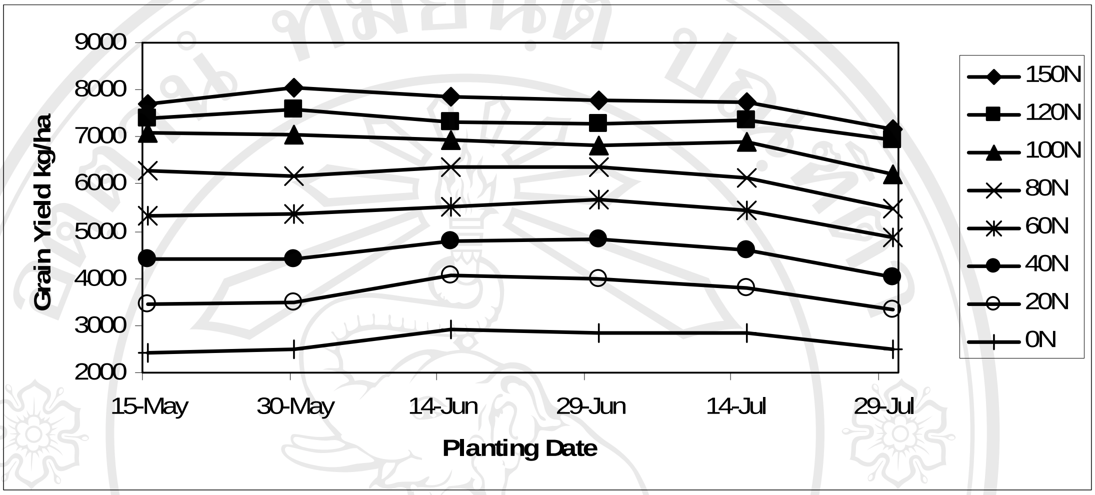

Figure 6.4: Effect of planting dates and fertilizer rates on IR-64 simulated grain yield at Omtekha.

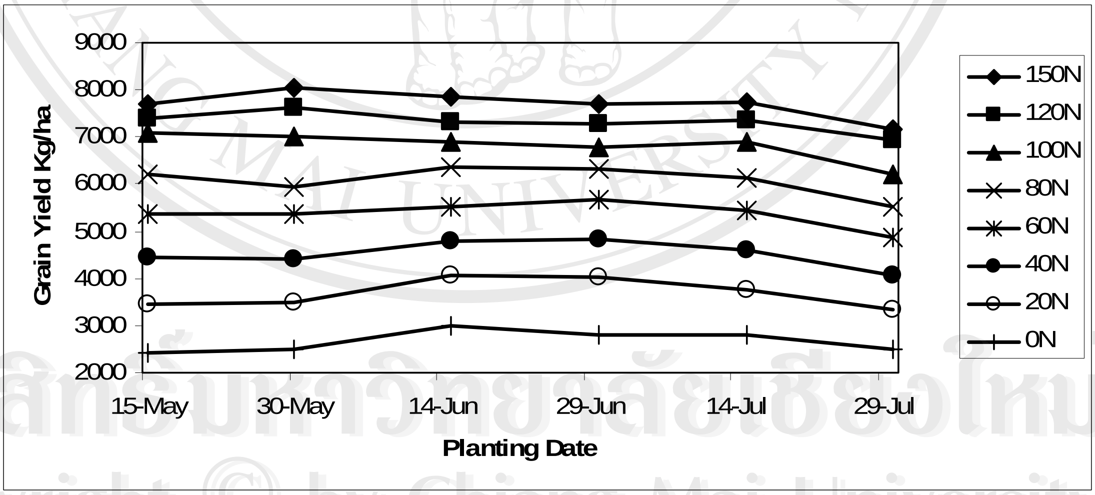

Figure 6.5: Effect of planting dates and fertilizer rates on IR-64 simulated grain yield at Wangjokha.

Increase in nitrogen rate increases the yield as well as make the variety more sensitive to planting time. Low rate of nitrogen has negligible effect on yield across different planting dates (Figures 6.4 and 6.5). On the contrary, higher nitrogen rate decreases the yield with planting done before 30th May or later than 30th June. Yield decrease after 15th July planting is sharp as nitrogen rate increases. Where as effect of planting date is minimal for treatments with low nitrogen rate. However, it was not statistically significant.

6.4.2 Response to nitrogen rate and planting time by BajoMaap2 and BajoKaap2

Effect of planting date and fertilizer rate on BajoMaap2 and BajoKaap2 were almost similar (Figures 6.6 and 6.7) to IR-64 except, we could see BajoKaap2 is more responsive to higher nitrogen application. On the other hand, BajoMaap2 had very less yield increase with the increase nitrogen rate. Similar to IR-64, difference in yield due to nitrogen rate is significant statistically but time of planting is not significant.

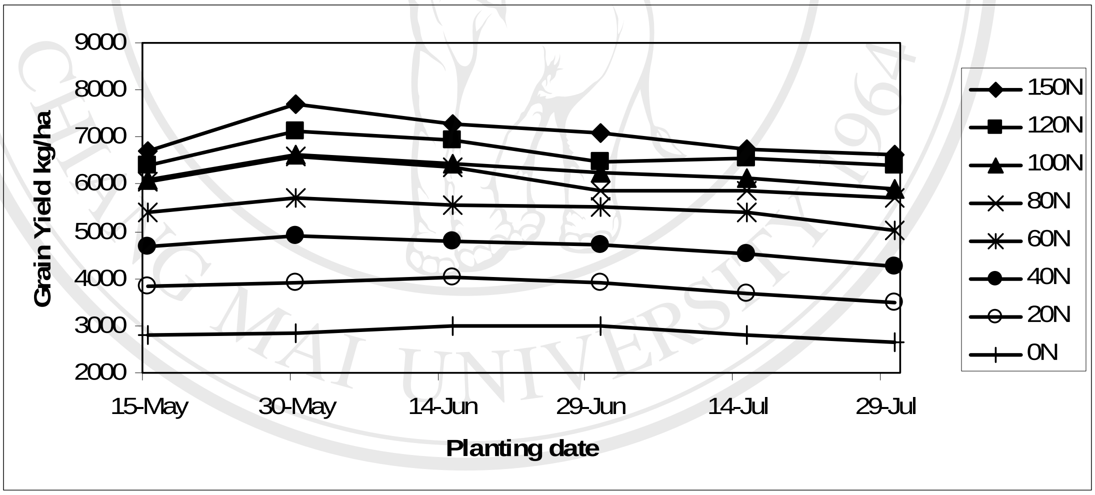

Figure 6.6: Effect of planting dates and fertilizer rates on BajoMaap2 simulated grain yield at Wangjokha.

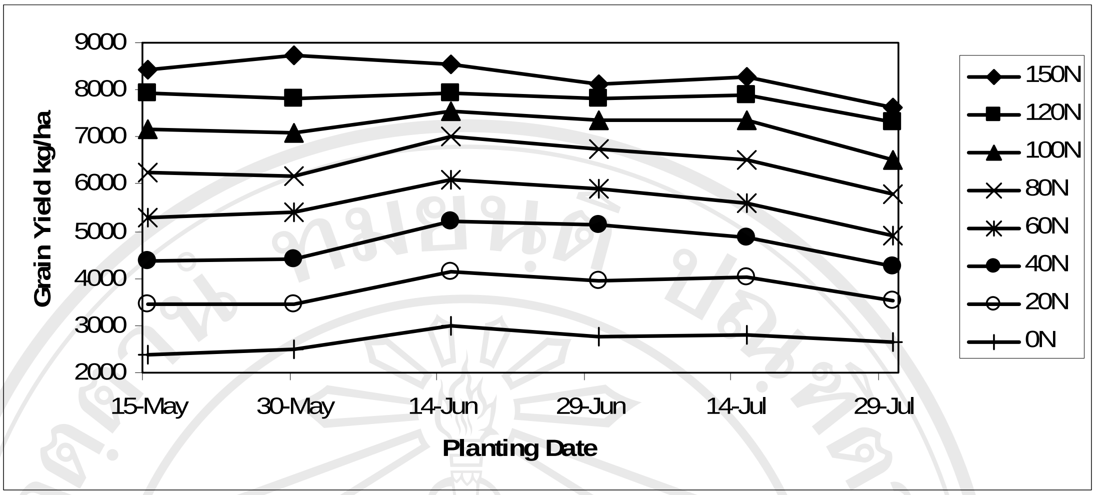

Figure 6.7: Effect of planting dates and fertilizer rates on BajoKaap2 simulated grain yield at Wangjokha.

As a general practice, farmers in the study area prefer to transplant rice around June when monsoon starts. This practice squeezes the planting time thus making the availability of scare resources like labor and water more acute. However, statistical analysis revealed that there were no significant yield differences due to planting date from 15th May to 30th July. But in reality it has been observed that planting after 15th July significantly reduces the yield. Therefore, it can be suggested that farmers can spread their transplanting time from 15th May to 15th July depending on the water availability without significant yield loss. However, other issues like pest and disease build up; cattle damage due to delay maturity etc should also be considered before implementing in the field.

6.4.3 Partial economic analysis of different nitrogen rate and plating time

Partial economic analysis was conducted to see the profitability of different treatments in the two villages. Analysis indicated that in both the villages positive net profit (break even) for IR-64 could be achieved with the application of 20N kg/ha and planting done on 30th June. Similarly, for BajoMaap2 and BajoKaap2 too positive net return (break even) could be achieved with 20 N kg/ha and planting on 30th June.

However, effect of planting could be influenced with the weather pattern which varies annually.

6.5 Varietal response to different nitrogen rate

Analysis also showed that all varieties give almost equal yield under low or medium nitrogen application (Figures 6.8 a,b,c) but as the fertilizer application rate increased performance of BajoKaap2 and IR-64 had also increased while yield of BajoMaap2 decreased. BajoKaap2 was found to be more responsive to higher nitrogen rate.

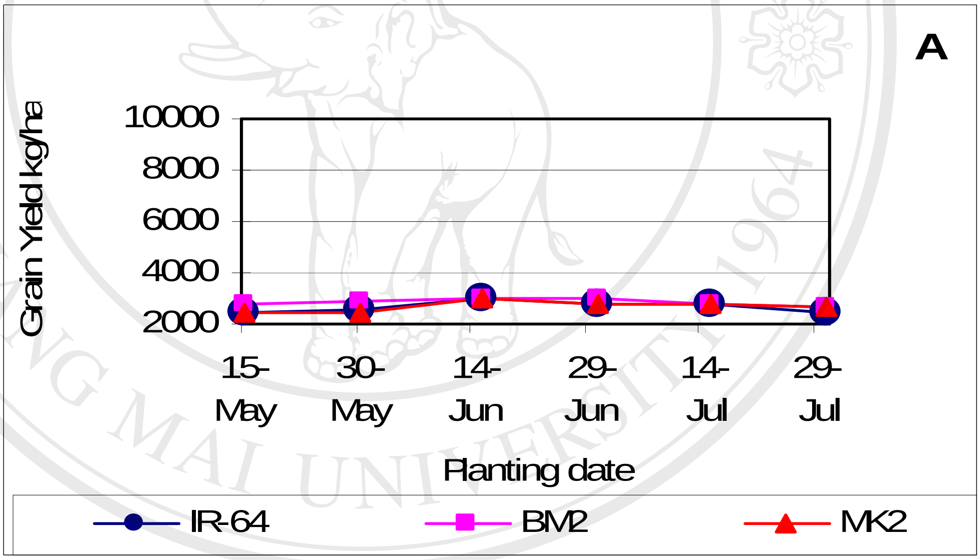

Figure 6.8a: Response of IR-64, BajoMaap2 and BajoKaap2 to 0 N kg/ha

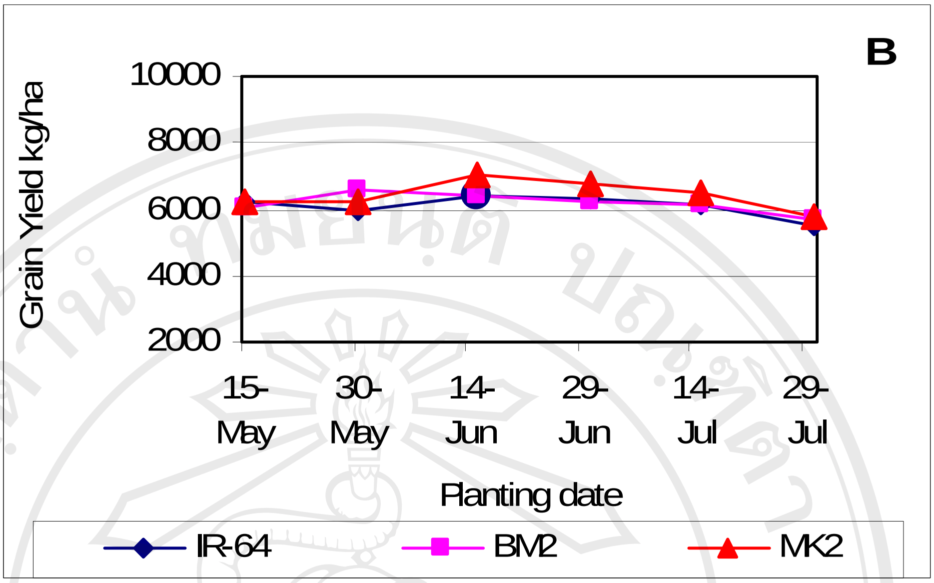

Figure 6.8b: Response of IR-64, BajoMaap2 and BajoKaap2 to 80 N kg/ha

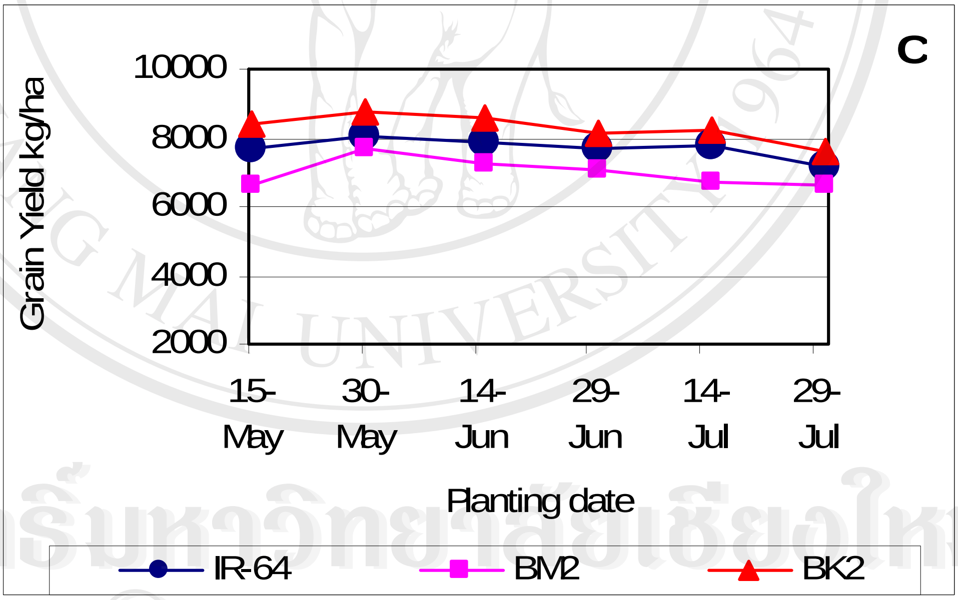

Figure 6.8c: Response of IR-64, BajoMaap2 and BajoKaap2 to 150 N kg/ha

Therefore, it can be concluded that BajoMaap2 was suitable for low nitrogen application, but if farmers can afford more nitrogen to increase yield then BajoKaap2 should be recommended.

Further, it can also be seen from simulation results that all three varieties produced higher yield for the planting done between 30th May and 30th June than other planting dates. With the increased nitrogen rate, 30th May planting gave slightly higher yield.

From the simulation result it was also seen that lower application of nitrogen rate has low standard deviation for different planting dates which indicate low risk. Higher application of nitrogen increases risk along with yield. Therefore, it can be concluded that it is one of the reason poor farmer (usually low risk taker) prefer to use low nitrogen rate.

With planting done from 30th May to 30th June with nitrogen rate above 60 kg/ha and 3,000 kg/ha FYM (Average N content of 1.2%), model simulated the yield of all three varieties near to the observed average farm yields of 4,813 kg/ha, 4,375 kg/ha and 4,680 kg/ha for IR64, BajoMaap2, and BajoKaap2, respectively. As such any attempt to narrow the yield gap of these three varieties could be possible with application of nitrogen above 60 kg/ha and planting done between 30th May and 30 June.