Secondary Crop Breeding for the optimal use of Rainfed Land and Rehabilitation of Critical Land

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Abstract

Rainfed land is defined as a field by which different type of crops were able to be cultivated without any access to irrigation. However, there is a draw back such as land becomes critical by the intensive use this kind of land for agriculture. The best way to cope with this kind of draw back is by improving the cultivation management system. Growing more than one crop on the same piece of land during one year calender reduce physical damage by rain, wind and soil erosion, eventhough the productivity of the recommended crops in the crop association normally gives a lower yield than in monoculture. Secondary crops such as upland rice and peanut are normally intercropped with different crops even perrenial ones, therefore breeding for their high yielding varieties suitable for the rehabilitation of critical land by the use of integrated system should be conducted. Upland rice is normally seeded directly and weeds are the major constraint for its optimal production. It has been reported that some local and red rice cultivars showed strong inhibitory activity to weed. Both cultivars are used for parental crossing. F4 population has been produced and identification of resistant lines is still in progress. Peanut can be cultivated in different types of critical land. Calcareous soil is an example of critical land. In such soil, iron is normally very limited. As a result, peanut leaves become chlorosis and pod is not able to develop. Breeding work will be based on selection of an individu originated from heterozygote populations on controlled environment using determined iron concentration media.

Keywords: Marginal land, upland rice, peanut, participatory breeding

Introduction

Rainfed land is defined as a field by which crops are normally cultivated without any access to irrigation (Utomo, 1998). Rainfed land shows very dynamic characteristics, means that different crops can be cultivated either monoculture or multiple cropping and yield properly, but due to population density and the development of market oriented farming system, the crop cultivation in rainfed land tends to use high external inputs or exploit local natural resource intensively (Reijntjes et al., 1992). However, both tendencies cause negative effect (Ruttan, 1999), because of land degradation, erosion, organic matter depletion and lastly declining productivity – land becomes critical (Badrun, 2000).

Number of critical land must be managed through changing land-use system and rehabilitating this land without any negative impact on national food security and farmer’s income. The use of rainfed land should consider the sustainability factor using integrated system including animal husbandry, fisheries, cultivation of perrenial and annual crops.

Multiple cropping is a dominant land cropping system in the developing countries (Francis, 1981). It is characterized by the use of low external input, intensive labour, local cultivar and as a result the productivity is very low. Nevertheles multiple cropping is a suitable cropping system to maximize production by reducing the risk and sustain the natural resources in agriculture (Reijntjes et al., 1992).

Secondary crops such as upland rice and peanut are annual crops, which are commonly cultivated sequentially or together by farmers in rainfed land (Basyir et al., 1995). They show a good potential for the development to support food security program (Lubis et al., 1995), because rotation of rice and legumes such as peanut can lead to stable and higher value production. Constraints in the rainfed land cultivation may be amount and time of water rainfall availability and also the existence of pest (Wade et al., 1999; Zeigler & Puckridge, 1995). Other constraints are poor soil fertility due to unappropriate land use, shadding and plant competitors.

Upland rice is normally seeded directly in the early of rainy season and weeds are the major constraint for its optimal production. Weeds reduce grain yield and quality. Yield-losses caused by weeds are estimated ranging from 30 to 100%. Peanut can fix free nitrogen and provide green feeder for animal and grain as a source of protein and income for a lot of farmer. Peanut can be cultivated in different land types after rice or directly in the early of rainy season. In calcarious soil, iron is the major constraint of peanut production. Although there are many constraint related to rainfed land, but the potential for raising yield is still possible, therefore the development of high yielding varieties which are suitable for sustaining the intensive used of rainfed land and can be exploited for the rehabilitation of critical land must be conducted (Lewis & Christiansen, 1981).

There are different types of rainfed land, the introduction of formal crop improvements which have been highly effective in producing input responsive, broadly adapted cultivars (Atlin et al., 2001), have brought little significant effect (Almerkinders and Elings, 2001). The strategy is then to encourage farmer to collabotare in the crop improvement program.

Research activities

1. Upland rice

There are two research activities related to upland rice. Because the major constraint of upland rice cultivation are water shortage and direct seeded system, the first experiment tries to study germination rate, shot and root relative growth rate in the early growth stage and their relation to plant height, root length and volume in the harvesting time of some accessions.

Table 1. Germination rate of some upland rice accessions (days)

Accessions	Germination rate
Mandura	2.35
Untup	2.77
K18	3.63
Tromas	3.50
K20	4.31
Salumpikit	3.47
K21	3.96
Mendalet	4.38
Depak	4.13
Rantau mudik	4.07
Lembayung gundil	3.71
Tholo	3.66
Brasil	2.36
S3 x 0	3.61
S 31 x Mn	4.67
S 1 x 50	3.91
Mayangan	4.43
S 4 x Mn	5.27
DPP 24	5.58
Saerah	2.65

A principal mechanism by rice has become adapted to water deficiency is through the possession of a pronounced root system by which maximises water capture and allows access to water at depth (O'Toole, 1982). Price & Tomos (1997) reported the use of hydroponically root growth for the identification of field drought resistance. Root and shot growth are affected by early growth capability and length of coleoptil (Blum, 1986).

Table 2. Shot and root relative growth rate at the first 30 days (cm/day), plant height (cm), root length (cm) and volume at harvest of some upland rice accessions.

Accessions	Relative growth rate		Plant height	Root	
	shot	root		length	volume
Mandura	2.20	0.25	142.25	42.00	43.00
Untup	1.90	0.27	129.25	35.75	39.75
K18	1.60	0.47	119.75	41.50	52.75
Tromas	0.98	0.20	132.50	46.75	87.25
K20	2.40	0.38	123.75	39.25	26.25
Salumpikit	2.22	0.47	129.25	35.25	37.50
K21	1.52	0.53	118.50	34.75	12.50
Mendalet	1.75	0.23	133.00	38.50	57.50
Depak	1.52	0.75	98.75	39.50	37.50
Rantau mudik	2.22	0.45	128.00	41.50	31.25
Lembayung gundil	2.50	0.13	138.25	44.50	87.50
Tholo	1.52	0.43	124.25	40.00	73.75
Brasil	1.97	0.28	131.25	32.75	50.00
S3 x 0	1.12	0.25	86.75	34.75	28.75
S 31 x Mn	1.42	0.15	95.00	38.25	62.25
S 1 x 50	1.29	0.15	95.25	33.00	27.50
Mayangan	2.19	0.17	136.00	42.50	50.00
S 4 x Mn	1.54	0.62	98.25	37.75	27.50
DPP 24	2.09	0.43	124.25	34.50	19.00
Saerah	1.67	0.30	108.25	41.00	23.75
HSD5%	0.81	0.65	19.63	14.30	41.52
GCV	22.61	33.70	13.51	7.12	45.41
Heritability	0.63	0.18	0.82	0.20	0.61

Note: HSD: Honestly significant different; GCV: Genetic coefficient of variability

Table 1 shows that there are variabilities in the germination rate. Mandura, Untup, Brazil and Saerah require less than three days whereas SP4xMn and DPP24 need more than 5 days to germinate. By an assumption that fast germination related to fast growing, seedling tests may be directly relevant for the evaluation of seedling drought tolerance, where seedling establishment and survival are very important characters (Blum, 1986). If fast germination relates to seedling establishment and survival in direct seeding. The use of fast germination cultivar may avoid the waste of 400-600 mm of rainfall. Direct seeding may allow allow planting of a second crop, which makes use of rainwater that arrives later in the season. The practice also reduces risk of drought where the rainy season is short, and because dry seeded cultivars can generate more roots. Only fast germination character may not support the ability of rice plant to survive in the very complex circumstance in the upland area. Vigorous root development and growth is apparently important for seedling survival under conditions where soil is rapidly drying, but sufficient moisture is available in the deeper zone. There are no significantly differences in the root relative growth rate (Table 2). Though the genetic variability of root relative growth rate is considered to be quite high (33.70%), but their growth is strongly affected by environment (h= 0.18). Different result is found by shot relative growth rate. There are significantly differences among the accessions. Some fast germination accessions such as Mandura, Untup and Brazil tend to grow fast with shot relative growth rate more than 1.90 which is not significantly diffferent compared to the fastest one (Lembayung gundhil). The genetic variability of shot relative growth rate character seems quite high even its heritability, therefore this character may be very useful for selection.

Early fast growth seedling tends to produce tall plant (Table 3). This tall character is normally not suited to modern cultivar due to its small harvest index and longer date of harvesting. Plant height shows significant correlation to the root length and the root length significantly determines the root volume. There is some unbelievable result, therefore further research shall be conducted.

Table 3. Correlation matrix between selected characters

Characters	SSGR	RRGR	PH	RL	RV
Shot relative growth rate (SRGR)	1.00	-0.140^{ns}	0.583^{*}	0.105^{ns}	0.154^{ns}
Root relative growth rate (RRGR)		1.00	-0.162^{ns}	-0.350^{*}	-0.090^{ns}
Plant height (PH)			1.00	0.353^{*}	0.194^{ns}
Root length (RL)				1.00	0.376^{*}
Root volume (RV)					1.00

In plant breeding for marginal land such as rainfed and critical land, fast early growth of root and shoot are required, so that the seedlings were able to survive in the easily dry land surface condition but water content in the deeper soil layer still support the crop growth. The speed early root growth is related also to the ability of crop in maintaining its potential water content in the leaves. Fast root and shoot growth in the early growth stage will also support the ability of crop to compete with weeds (Andreas & Clement, 1984). Though there is no different in root growth rate, but fast germination accessions provided either better end root length or volume, therefore selection based fast germination and shot growth may enhance the possibility of developing upland rice.

Weeds are one of the major constraints to crop production worldwide (Olofsdotter et al., 2002). Weeds reduce upland rice grain yield and quality. Estimates of yield losses caused by weeds in upland rice range from 30 to 100%. Breeding for weed resistant is started in 1993. The first objective is introducing the concept of allelopathy in the breeding program. More productive tiller number which is formed very fast in the early of vegetatif stage may also improve the competition ability to weeds. Tabel 4 shows the performance of selected lines developed for weeds resistant in farmer field. Selection based on productive tiller number affected the plant height, panicle length and seed number. The reduction of plant height, panicle length and seed number per panicle are dependent upon the selected lines. Increasing the number of productive tiller will decrease the percentage of baren seeds.

2. Peanut

Calcareous soil is classified as any soil containing sufficient calcium carbonate (Brady, 1990). The problems of calcareous soil are deficiency of several micronutrients such as iron, manganese and copper. Iron deficiency results from the low availability due to high pH (7.5 – 8.2) and limits legume production (Osotsapar, 2000). The best way to cope with iron deficiency in peanut is by cultivar development. Chen & Barak (1982) proposed two steps system. First is quick screening procedure, in which seedlings are grown in nutrient solution containing 0.2 ppm iron as FeHEDTA. After six days, plants are graded for chlorosis. Secondly, promising cultivars are cultivated in the field to measure their yield potential.

Table 4. Gain of selection based on productive tillering number from some selected F_3 populations.

Selected lines	Characters	Selected population		Difference (%)
		F_3	F_4	
Poso X Tondano	Productive tiller number	15.00	21.67	44.44
	Plant height (cm)	141.75	86.13	-39.24
	Panicle length (cm)	27.75	23.00	-17.12
	Seed number	203.75	157.73	-22.58
	Normal seed (%)	73.35	91.09	24.19
Tondano X Ranau	Productive tiller number	13.00	18.31	40.83
	Plant height (cm)	134.25	73.77	-45.05
	Panicle length (cm)	28.25	23.54	-16.68
	Seed number	275.00	161.77	-41.17
	Normal seed (%)	78.33	90.55	15.60
Tondano X L. Tawar	Productive tiller number	14.50	159.00	31.03
	Plant height (cm)	159.50	81.00	-49.22
	Panicle length (cm)	30.00	25.83	-13.89
	Seed number	209.00	181.00	-13.40
	Normal seed (%)	77.00	91.83	19.26
Maninjau X Singkarak	Productive tiller number	10.50	14.91	41.99
	Plant height (cm)	147.25	92.46	-37.21
	Panicle length (cm)	27.00	24.64	-08.75
	Seed number	254.25	178.09	-29.95
	Normal seed (%)	80.17	81.35	1.46
Ranau X Maninjau	Productive tiller number	11.75	13.71	16.72
	Plant height (cm)	148.75	86.86	-41.61
	Panicle length (cm)	28.50	24.64	-13.53
	Seed number	272.75	165.29	-39.40
	Normal seed (%)	68.80	81.86	18.98
Ranau X L. Tawar	Productive tiller number	11.75	15.27	29.98
	Plant height (cm)	175.67	93.00	-47.06
	Panicle length (cm)	27.25	24.86	-8.76
	Seed number	192.75	157.45	-18.31
	Normal seed (%)	77.75	85.95	10.54
D. Tempe X D. Bawah	Productive tiller number	13.50	18.70	38.52
	Plant height (cm)	141.00	81.50	-42.20
	Panicle length (cm)	28.13	23.90	-15.02
	Seed number	310.00	154.80	-50.06
	Normal seed (%)	78.20	87.23	11.55

There are two cultivars in the institute, which are considered to be resistant and sensitive. Two of them are explored to develop selection medium based on MS (Murashige & Skoog, 1962) for breeding for low iron resistant. First trial tries to know the effect of iron content in the media (0.00, 6.95, 13.90, 20.85, 25.02, 27.80 mg/l $FeSO_4$ x 7 H_2O) on the seedlings height, shot diameter and weight (Table 5).

Table 5. Analysis of variance on the effect of iron concentrations on seedling quality

Source of variation	Degree of freedom	Sum of square		
		Plant height	Shot diameter	Shot weight
Variety	1	05.627*	0.000^{ns}	0.026^{ns}
Iron concentration	5	18.783*	0.003^{ns}	0.177*
-. Linear	1	06.223*	0.000^{ns}	0.051^{ns}
-. Quadratic	1	00.812^{ns}	0.002^{ns}	0.009^{ns}
-. Qubic	1	03.116^{ns}	0.000^{ns}	0.003^{ns}
Interaction	5	11.358	0.001	0.063^{ns}
Error	23	31.191	0.009	0.031

Iron concentration in the media affects the seedling height and shot weight. The effect to seedling height tends to be linear. Chlorosis is detected on free iron medium 3 weeks after planting. Due to slow effect of free iron medium, another experiment to minimize the iron content in the medium by increasing PH (5.5, 6.0, 6.5, 7.0, 7.5, 8.0) is conducted (Table 6).

Table 6. Analysis of variance on the effect of selection medium pH on some seedling quality parameters

Source of variation	Degree of freedom	Sum of square		
		Plant height	Shot diameter	Shot weight
Variety	1	158.080*	0.015^{ns}	0.251^{ns}
pH	5	19.948^{ns}	0.018^{ns}	1.714^{ns}
-. Linear	1	0.000^{ns}	0.002^{ns}	0.001^{ns}
-. Quadratic	1	1.642^{ns}	0.001^{ns}	0.143^{ns}
-. Qubic	1	9.976^{ns}	0.004^{ns}	0.482^{ns}
Interaction	5	15.658^{ns}	0.001^{ns}	1.272^{ns}
Error	24	46.489^{ns}	0.025	7.025

3. Participary crop improvement

Crops, which are cultivated in marginal land, suffer droughts, floods, pests, weeds, and soil constraints. Since most marginal lands depend on erratic rainfall, conditions are diverse and unpredictable, farming systems in marginal environments are too different from those more favourable production areas (Hardon & de Boef, 1993). Many breeding objectives are developing high yielding variety which shows a broad adaptation, whereas the importance of adaptation to variable and risky conditions have received only little or no attention due to economic reason (Almekinders & Elings, 2001). There is a huge amount of marginal land around the world and the potential for raising yield is still possible, therefore there is a challenge to develop suitable varieties. Universitas Gadjah Mada is supported by almost 160 hectars marginal land by which there are around 350 farmer families working in the area. Started in 2002, these farmers will be encouraged to participate in peanut breeding.

References

Almekinders C.J.M., Elings A. 2001. Collaboration of farmers and breeders: participatory crop improvement in perspective. Euphytica 122: 425 - 438

Andreas L. A., Clement S. L. 1984. Opportunities for Reducing Chemical Inputs for Weed Control. **In** Organic Farming: Current Technology and Its Role in a Sustainable Agriculture. ASA Special Publication Number 46. Kral et al. (Eds.). American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. Madison. 129 - 140

Atlin G.N., Cooper M., Bjornstad A. 2001. A comparison of formal and participatory breeding approaches using selection theory. Euphytica 122: 463 - 475

Badrun M. 2000. Peluang Pengembangan Lahan Kering untuk Mendukung Kebijaksanaan Ketahanan Pangan Melalui Penerapan Sistem dan Teknologi Usaha Budidaya Tanaman Berkelanjutan. Suatu Kerangka Konsepsi. Fakultas Pertanian, Universitas Gadjah Mada. Forum Terbatas

Basyir A., Purnanto, Suyamto, Supriyatin 1995. Padi Gogo. Balai Penelitian Tanaman Pangan. Malang

Blum A. 1988. Plant Breeding for Stress Environments. CRC Press Inc. Florida

Brady N.C. 1990. Nature and Properties of Soils. 10th edition. Macmillan Publ. Co. New York.

Chen Y., Barak P. 1982. Iron nutrition of plants in calcareous soils. Advances in Agronomy 35: 217 - 240

Francis C. A. 1981. Development of Plant Genotypes for Multiple Cropping Systems. **In** Plant Breeding II. Frey (ed.). The Iowa State University Press. Iowa. 179 – 232

Hardon J., de Boef W. 1993. Linking farmers and plant breeders in local crop improvement. **In** Cultivating Knowledge. Genetic Diversity, Farmer Experimentation and Crop Research. De Boef et al. (eds). ITP. London. 64 - 67

Lewis C.F., Christiansen M.N. 1981. Breeding Plants for Stress Environments. **In** Plant Breeding II. Frey (ed.). The Iowa State University Press. Iowa. 151 - 178

Lubis, Harahap E. Z., Diredja M., Kustianto B. 1995. Perbaikan Varietas Padi Gogo. Prosiding Simposium Penelitian Tanaman Pangan III. 437 - 447

Murashige T., Skoog F. 1962. A revised medium for growth and bioassays with tobacco tissue cultures. Physiologia Plantarum 15: 473 – 497

Olofsdotter M., Jensen L.B., Courtois B. 2002. Improving crop competitive ability using allelopathy – an example from rice. Plant Breeding 121: 1 - 9

Osotsapar Y. 2000. Micronutrients in Crop Production in Thailand. Food & Fertilizer Technology Center. Extention Bulletin 488.Taiwan

O'Tolle J.C. 1982. Adaptation of rice to drought prone environment. **In** Drought Resistance in Crops with Emphasis on Rice. IRRI. Manila. 195 – 213

Price A.H., Tomos A.D. 1997. Genetic dissection of root growth in rice (Oryza sativa L.). II: mapping quantitative trait loci using molecular markers. Theoritical and Applied Genetic. 95: 143 - 152

Reijntjes C., Haverkort B., Waters-Bayer A. 1992. Farming for the Future. An Introduction to Low-Input and Sustainable Agriculture. ETC/ILEIA. Luesden

Ruttan V. W. 1999. The Transition to Agricultural Sustainability. Proc. Natl. Sci. USA 96: 5960 - 5967

Utomo M., 1998. Peranan Olah Tanah Konservasi Lahan Kering. **In** Budidaya Tanaman Sela di Perkebunan/Kehutanan. Lokakarya Sehari Mengenai Sistem Tanam, Tanpa Olah Tanah, Bioteknologi Tanaman & Sistem Pencegahan Hutan dan Kebun. Jakarta

Wade L. J., Fukai S., Samson B. K., Ali A., Mazid M. A. 1999. Rainfed Lowland Rice: Physical Environment and Cultivar Requirements. Field Crops Research 64: 03 - 12

Zeigler R.S., Puckridge D.W. 1995. Improving Sustainable Productivity in Rice-based Rainfed Lowland Systems of South and Southeast Asia. Feeding 4 Billion People. The Challenge for Rice Research in the 21st Century. Geo J. 35: 307 - 324