High bed systems for off-season vegetable production in the Tropics and Subtropics

To stop further destruction of tropical highland and marginal land, vegetable production has to be increased in existing agricultural areas in densely populated, and typically rice-based tropical lowland. The goal is to overcome flooding in the summer rainy season by the agronomic practice of raising the bed height instead of inducing flood-tolerance in vegetables. Permanent high bed agriculture might have this potential.

The idea of building »raised fields« for agricultural crop production reaches back 4,000 years in Central and South America. »Chinampas« of enormous sizes supported large, dense populations in tropical lowlands for long periods of time (Turner & Harrison, 1981). In recent time, a rehabilitation of these raised fields for modem agricultural use is being considered (Werner, 1994).

At present, permanent high bed agricultural systems can be found throughout South East Asia (e.g. in India (Singh & Gangwar, 1989) and China (Chiu, 1987; Plucknett & Beemer, 1981). Complex rotation and intercrop patterns make maximum use of time and space in limited areas, particularly in peri-urban regions. But it is by far more common to grow vegetables on flat beds. Research in this field at the Asian Vegetable Research and Development Center - AVRDC - during the last 20 years has therefore, focused on raising bed heights temporarily for a single crop (AVRDC, 1979-94). The potential benefits in terms of yield have been proven repeatedly, but the economic analysis showed that additional yield benefits from temporarily built high beds are not likely to offset the additional construction costs involved (Table 1).

Applying a permanent high bed system the costs for construction and even more for reconstruction can be covered by a number of crops. Since high bed planting has not proven beneficial for crops in the dry season, the economic advantage of the system depends solely on the performance of vegetable crops grown in the rainy season. Through the right choice of suitable vegetable species as summer crops, a permanent high bed system has shown its superiority over ordinary flat bed cultivation, in a trial conducted at AVRDC, during the first year crop sequence (Table 2).

Layout of a permanent high bed vegetable production system

Due to the fact that the hard plow pan was initially developed for traditional rice cul-

Table 1: Economy of temporary high beds in AVRDC 1979 -1994

Bed height (cm)	Yield (kg/m²)	Construction costs high beds (NT$/m²)	Market price vegetable to offset construction costs (NT$/kg)	Possibility to achieve market price
Tomato 1979				
15	0.57			
30	2.09	20.85	13.70	likely
Tomato 1981				
15	0.11			
30	0.82	20.85	29.40	doubtful
45	0.91	41.70	52.10	unlikely
Chinese cabbage 1981				
15	0.63			
30	1.21	20.85	36.00	unlikely
45	1.43	41.70	52.10	unlikely
Chillie 1992				
20	1.01			
30	1.42	13.90	33.90	likely
40	1.73	27.80	38.60	likely
Tomato 1994				
20	1.02			
40	0.89	27.80	-	impossible

Table 2: Economy of permanent high beds in AVRDC 1993/1994

Crop	Yield high beds (kg/m²)	Yield flat beds (kg/m2)	Market price vegetable (NT$/kg)	Contribution to construction costs (NTS/m²)
Chinese cabbage	2.16	1.37	19.16	15.14
Chillie, 1. harvest	0.12	0.03	44.97	4.05
Chillie, 2. harvest	0.12	0.03	44.97	4.05
Chillie, 3. harvest	0.57	0.12	39.87	17.94
Chillie, 4. harvest	0.19	0.10	21.30	1.92
Carrot	1.20	1.29	7.01	-0.63
Vegetable Soybean	1.12	1.26	48.20	-6.75
			Total	35.72

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tivation, this does not anymore allow to dig low ditches deeper than about 40 to 50 centimetres; hence the width of the fur-rows is decisive for the final height of high beds. The dimensions of the furrows depend on whether they are to serve as irrigation/drainage channel, walking space, or as cultivation area for preferably aquatic crops (e.g. rice). Bed construction and reconstruction has to be done in the dry season. In order to provide optimal conditions for the summer crops, work should be done early in the dry season to allow for some reinforcement during winter crop production which will prevent erosion during summer crop production.

Integration of upland vegetable crop (vegetable soybean) and lowland aquatic crop (watertaro) in a permanent high bed agricultural system. *Photo: Kleinhenz*

The labour input for construction, reconstruction and maintenance of permanent high beds is high, but can be partially saved through mechanization. Since vegetable production is generally labour-intensive, the costs of high bed construction are not excessive when related to the other costs of production.

High bed systems in South East Asia show a wide range of different bed widths. While results gained from the trials at AVRDC show no significant yield differences for various bed widths, there is an indication that the effects (positive or negative) of high bed cultivation are likely to decrease with increasing bed width.

Figure 2: Chillie yield September – November 1993

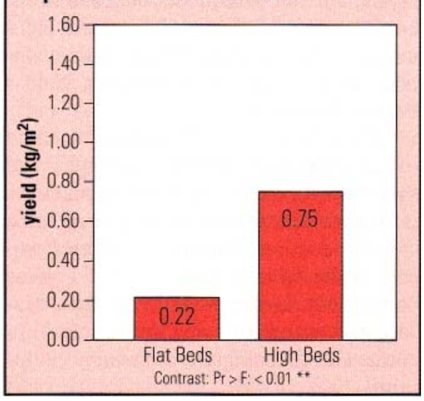
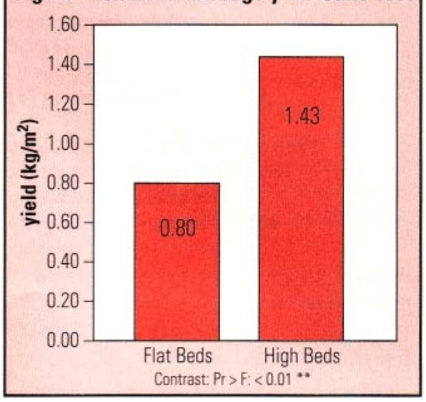


Figure 1: Chinese cabbage yield June 1993



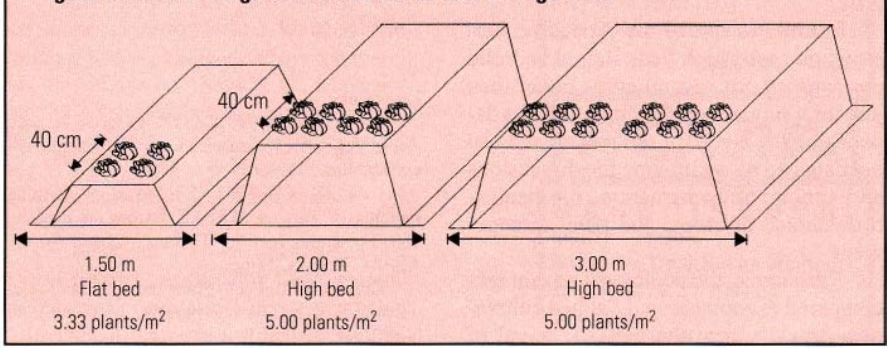
Market prices of vegetables vary considerably between the dry and rainy sea-sons. To achieve highest benefits in a permanent high bed system, vegetable species mainly susceptible to flood should be chosen. Chinese cabbage and chillie peppers have proven their potential as summer crops on high beds in AVRDC (Figures 1 and 2).

Crop arrangement on high beds should be based on interrow and interplant distances rather than plant densities to achieve optimum performance (Figure 3).

Growth factors in a permanent high bed vegetable production system

In vegetable growing the most serious damages due to floods are caused by an-

Figure 3: Plant arrangement on flat beds and on high beds



aerobic conditions in the root zone, which prevent water uptake by the plant. Dam-age is also caused by the disruption of the plants' hormone system (Kramer, 1969). Further disadvantages for vegetable growing on flat beds might result from the tropical climate and unvaraurable soil conditions on a formerly traditional rice-growing field

To overcome flood stress in vegetable production, the high bed cultivation system is based on removal of excessive soil moisture by better drainage, indicated by higher water infiltration rates.

However, higher water intake rates make high beds more drought prone in the dry season: Since the furrows are continuously flooded, soil water content decreases towards the center of the beds as do crop yields (Figure 4). During the rainy season yields are supposed to increase to-wards the dryer parts of the beds, but this effect is not very obvious.

In rice soils, the root system of vegetables is typically restricted to the topmost surface soil when grown on flat beds. In contrast, root growth of vegetable crops on high beds is generally better. Although roots do not grow absolutely deeper, a far higher root density is found in the 30 to 50 centimetre soil layer. Lower water content and, consequently better oxygen supply in deeper soil layers is expected to be the main reason for enhanced rooting of vegetables on high beds.

The mineralization rate of organic bound nitrogen is higher on flat beds during the dry season. At the same time, mineralized nitrogen decreases more rapidly with soil depth in flat beds than in high beds. Through a multiple regression analysis of crop petiole sap NO3 concentration against concurrent soil NO3 concentration (Westcott & Knox, 1994) in different soil layers it can be shown that vegetables grown on high beds also take up nitrogen from below 30 centimetres depth (Figure 5). In contrast, since root distribution in flat beds is restricted to the topsoil, soil nitrogen in subsoil layers is not plant-available and susceptible to loss. There-fore, high bed cultivation prevents and environmental pollution.

Figure 4: Pak Choi yield February 1993 on high beds as influenced by soil water content

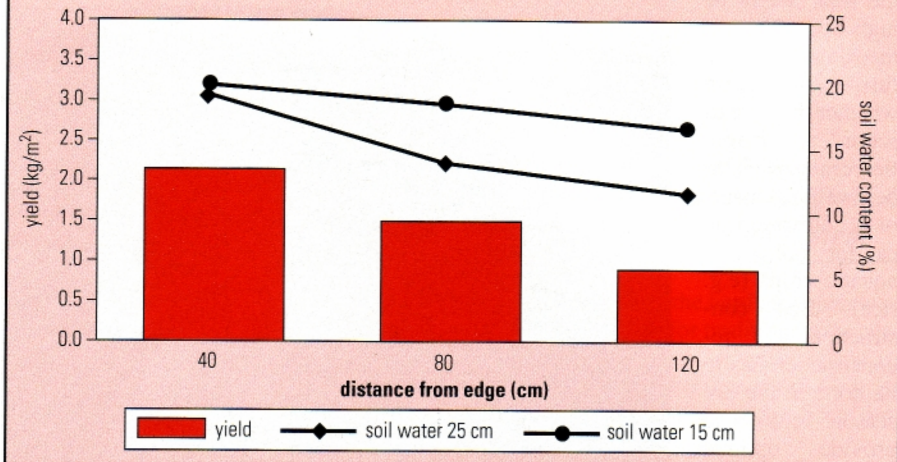


Figure 5: Multiple regression analysis plant nitrate = f (soil nitrate) of vegetable soybean, March-May 1994

Flat beds: Plants $NO_3^- = 127.3^{n.s.} + 12.1^{**} \cdot$ Soil NO_3^- (0 – 30 cm) – $8.5^{n.s.} \cdot$ Soil NO_3^- (30 – 60 cm)

High beds: Plant $NO_3^- = 398.3^{*} + 15.9^{**} \cdot$ Soil NO_3^- (0 – 30 cm) + $22.9^{**} \cdot$ Soil NO_3^- (30 – 60 cm)

Plant NO_3^-: Plant sap nitrate [ppm]
Soil NO_3^-: Soil nitrate [kg N/ha]
n. s.: not significant; *: significant (5 % level); **: high significant (1 % level)

Summary and conclusion

High bed systems have been known since ancient times and are in use in various regions throughout tropical and subtropical Asia.

In order to spread the expensive construction costs, high beds should be build permanently for several crops rather than just for a single crop. Profitability also depends on the layout of the system and can be managed by optimizing the dimensions and timing of construction, mechanization, choice of crops, and plant arrangement.

Agronomic and ecological advantages compared to conventional flat bed cultivation develop from the better removal of excessive moisture, particularly in subsoil layers, which consequently leads to deeper root penetration, stability of the NO3-ion, and finally enhanced soil nitrogen uptake by the crop which prevents N loss through leaching.

Integrating of the traditional method of constructing permanent high bed systems with modern agronomic practices is a path towards increasing vegetable crop production in tropical and subtropical, typically rice-based lowland areas particularly during the rainy summer season, and towards raising the farmers' income, and reducing environmental pollution.

Bibliography

AVRDC 1979-94: AVRDC Progress Report. Asian Vegetable Research and Development Center. Shanhua, Tainan.

Chiu, C. C., 1987: Evolution of farming systems in Taiwan. ASPAC Extension Bulletin 265. Food and Fertiliz. Technol. Center for the ASPAC Region, Taipei.

Kramer, P. J., 1969: Plant and soil water relationships: A modem synthesis. McGraw-Hill, New York.

Plucknett D. L., Beemer, H.L. (eds.), 1981: Vegetable farming systems in China. Westview Press, Boulder.

Singh; S., Gangwar, B., 1989: Integrated farming systems for Bay Islands. Indian Farming 89(2). 21-24.

Turner, B. L., Harrision, P. D., 1981: Prehistoric raised-field agriculture in the Maya lowlands. Science 213.399-405.

Werner. L., 1994: The chinampa system: marshland magic of the Aztecs. Ceres 147. 12-13.

Westcott, M. P., Knox, M. L, 1994: Kinetics of soil-plant nitrate relations in potato and peppermint: A model for derivative diagnosis. Commun. Soil Sci. Plant Anal. 25(5&6), 469-478.

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