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Impact of walking catfish (*Clarias batrachus*) on growth of water chestnut (*Trapa bispinosa*) and waterhyacinth (*Eichhornia crassipes*) in waterlogged ecosystem

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ABSTRACT

In an integrated aquaculture and aquatic crop cultivation system, comparative growth analysis of aquatic crop, water chestnut (*Trapa bispinosa* Roxb.) and waterhyacinth [*Eichhornia crassipes* (Mart.) Solmes], a weed in waterlogged areas, was carried out to understand the extent of interference of waterhyacinth on growth and fruit yield of water chestnut and associated yield of fish. Growth of water chestnut was faster during the first 2 months after planting, and thereafter the growth rate of waterhyacinth was faster and suppressed growth of water chestnut. Fast-growing waterhyacinth restricted leaf area development and affected crop growth rate of water chestnut. Flowering frequency of the water chestnut plants, which had an influence on fruit initiation and yield, was also severely reduced in the presence of waterhyacinth vegetation. Fruits were smaller, with pale-colored peels. The coexistence of waterhyacinth caused 93% decrease in the yield of water chestnut from 3.96 t ha^{-1} to 0.25 t ha^{-1}. Survival rate of walking catfish [*Clarias batrachus* (Magur)] was highest (68%) in plots with water chestnut followed by waterhyacinth-infested plots (44%). The highest fish yield (1.8 t ha^{-1}) with higher mean body weight (360 g) was noted in plots with water chestnut compared to fish yield of 0.79 t ha^{-1}, with average mean body weight of 224.5 g in plots with both water chestnut and waterhyacinth. Gut contents analysis showed 25 to 30% natural food from the ambient ecosystem when fish was reared with water chestnut. Infestation of waterhyacinth not only suppressed growth and yield of water chestnut, but also significantly reduced the growth and yield of fish, probably due to competition for space and nutrients, very low primary productivity, and low-intensity light penetration. However, walking catfish and water chestnut could be grown together, as fish with water chestnut recorded the highest production size index (648), performance index (194.9), and apparent feed conversion ratio (1.39). Therefore, a fish + water chestnut system provided better aquatic environment than a fish + waterhyacinth system, and a reduction of supplemental fish feed of 25 to 30% by this fish + water chestnut coproduction system increases productivity of the system.

Key words: *Clarius batrachus*, *Eichhornia crassipes*, *Trapa bispinosa*, waterlogged area.

INTRODUCTION

Water chestnut (*Trapa bispinosa* Roxb.) is an economically important aquatic crop (Reddy et al. 2002) grown mostly in shallow waterlogged areas of eastern and northern India, where raising other crops during the monsoon is risk prone (Banerjee and Thakur 1980, Hazra et al. 1996, Ahmed and Singh 1999). The nutritionally rich kernels of water chestnut fruit (Gopalan et al. 1987, Roy Chowdhury et al. 2004) are usually consumed fresh or boiled. Commonly, two types of fruits are available and sold in the market, i.e., fruits with green or red peels. Because they grow in waterlogged areas, water chestnuts encounter competition for space over the surface of water bodies from another plant—waterhyacinth [*Eichhornia crassipes* (Mart.) Solmes]—an omnipresent weed in unattended water bodies in eastern India.

Furthermore, the ecology and environment suitable for water chestnut and waterhyacinth is equally conducive for rearing of air-breathing fish, which can easily be integrated with each other. Among air-breathing fishes, walking catfish [*Clarias batrachus* (Magur)] is a highly priced species, fetching more than US$2 kg^{-1}. Owing to its taste, flavor, and medicinal value, walking catfish has high consumer preference in India and the Asian subcontinent. This species is well adapted and almost insensitive to adverse ecological conditions of derelict waterlogged ecosystems, which are mostly characterized by decaying vegetation and organic load coupled with poor nutrient release; low pH, oxygen, and primary productivity; and high carbon dioxide (CO_2), hydrogen sulfide (H_2S), ammonia (NH_3), etc. Identical habitat preference of water chestnut and walking catfish therefore provides an opportunity for their integration. In this communication, we report comparative growth response of water chestnut along with waterhyacinth with and without walking catfish. The relationship of plant growth with that of an air-breathing fish is also reported and discussed. The addition of a fisheries component and the effect of plant existence on fish growth have also been assessed. Few reports are available that discuss growing water chestnut in combination with aquaculture; they are mostly from Bihar and part of West Bengal (Jhingran et al. 1991, Banerjee and Thakur 1980). Water chestnut is an

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important crop in low-lying waterlogged areas, where fishes find their natural habitat. But there is limited awareness of the concept of integration of water chestnut cultivation with aquaculture. Likewise, very little information is available regarding effect of existence of waterhyacinth on growth, development, and yield of water chestnut (Poddar 2003, Roy Chowdhury et al. 2003), particularly when grown in association with aquaculture in low-lying waterlogged areas during the monsoon. Thus, this present attempt and information regarding integration of aquaculture with aquatic crop production will not only help to bring nonproductive waterlogged areas into production system but will also intensify use of water, increasing its overall productivity on both temporal and spatial scales in water-rich regions, avoiding its waste.

MATERIALS AND METHODS

An experiment was carried out in the Research Farm of Water Technology Centre for Eastern Region (20°30′N; 87°48′10″E) from June to December of 2004 and 2005 by growing water chestnut in combination with waterhyacinth and air-breathing fish. The experiment was a randomized block design with three replications. The four treatments were T_1, fish; T_2, fish + water chestnut; T_3, fish + waterhyacinth; and T_4, fish + water chestnut + waterhyacinth. Plot size was 4 by 5 m, and ponding depth during the experimental period ranged between 0.5 and 1.2 m. Compost manure at 8 t ha^{-1} was applied to the water body during the last week of May before the arrival of the monsoon.

Field preparation

Field preparation was done by plowing the semidry pond bed with a spade, turning the topsoil down to a depth of 6 cm. Cow manure at 8 t ha^{-1} was applied at the time of field preparation during early June just before the onset of the monsoon. The field was left as such until rainwater slowly filled the pond to a depth of 0.5 m in mid-June. Four different treatments in three replications were maintained in 5- by 4-m split bamboo sheets placed at the bottom of the pond to a height of 1.8 m to maintain additional barrier height of at least 0.5 m lest water reached to the brink of the pond at 1.3 m. Additional lining with nylon netting of fine mesh was also provided along the bamboo sheet partition to prevent any migration of fish from one treatment to another. Even though crops can survive a higher water depth, higher yield is obtained when depth is maintained within 1.5 m. A layer of 15 to 25 cm of soft mud (rich in organic matter) at the bottom of the water body was used to favor better growth of water chestnut.

Two types of water chestnut cultivars were used in the experiment. Before planting, seedlings from the nursery should be given a combination treatment of fungicide and insecticide, i.e., captan or carbendazim at 0.1% with chlorpyrifos at 0.2% by dipping overnight (12 h). The cultivar 'Haldipada green', bearing green-peeled fruits, is referred to hereafter as green cultivars, and cultivars bearing red-peeled fruits, 'Haldipada red', as red cultivars. The red cultivars also contain red pigments on the abaxial surface of their leaves and on stems, and can be distinguished at vegetative stage. Planting of water chestnut seedlings was done (1 m^2 in 50 : 50 ratio of red and green cultivars) with or without the same amount of waterhyacinth plants (1 m^2) per plot on 12 June. Three to four young water chestnut seedlings were loosely tied at the bottom in a knot. The knot was planted in the mud bottom of the water body by a gentle push with a toe, avoiding tearing of seedlings. A spacing of 1.5 by 1.5 m was maintained, and 12 planting spots in a 5- by 4-m plot had six spots each for green cultivars and red cultivars. On the surface of the water body in each plot, at four seedlings per spot there were 24 green and 24 red seedlings occupying 1 m^2 of water surface area. Approximately 4,400 bundles of seedlings (each containing three to four seedlings) are required to cover 1 ha. Similarly, 48 waterhyacinth seedlings occupied 1 m^2 of water surface area. Waterhyacinth seedlings were left afloat on the water surface. The experimental field was fertilized with N, P, and K in 40 : 60 : 40 kg ha^{-1} ratio in three equal splits. At the time of field preparation, one-third of N and K along with full dosage of P was applied before planting. The remaining two-thirds of N and K were applied in two splits at the second and fourth months after planting (MAP) as per standardized fertilizer schedule for water chestnut in shallow waterlogged conditions.

The fresh weight of the harvested samples collected from known area was measured, and subsequently the dry weight of the same was recorded after oven-drying at 80 C until constant dry weight of sample was reached. Crop growth rate of water chestnut and waterhyacinth either as sole crop or in combination was calculated following standard formula (Hunt 1990).

Aquaculture operation

In each plot, 7,500 walking catfish ha^{-1} (16.5 g mean body weight [MBW]) were released into the system 2 MAP, and rearing continued for 120 d. The plot without any plants, and only fish, served as control. Supplemental feed (rice bran and groundnut oil cake at 1 : 1 ratio by weight, provided in the form of moist dough) at the rate of 3.5, 3, 2.5, and 2% of MBW was given twice a day (7:00 to 8:00 A.M. and 4:00 to 5:00 P.M.), from the first, second, third, and fourth month to harvesting, respectively. Monthly samplings were carried out for assessment of growth and general health of fish. For this purpose, 12 fishes from each treatment, i.e., four fishes per replication, were sampled. The sampled fishes were measured (in millimeters), weighed (in grams), and released back in to the system after sampling. Phyto- and zooplankton estimation, weekly observations (samples were collected between 7:30 and 8:30 A.M.) of water quality (temperature, pH, dissolved oxygen, total alkalinity, transparency, primary productivity, total suspended solids, dissolved organic matter, nitrite $(NO_3)^4$, nitrate $(NO_2)^4$, ammonia^4, etc.) and monthly observations of soil quality (pH, available N, P, and organic carbon) were recorded using standard methods (APHA 1989, Biswas 1993). Field test instruments were also in use to

Table 1. Treatment-wise mean minimum and mean maximum values of various water quality parameters.

Parameter[1]	Manufacturer[2]	Control (only fish) —T_1	Fish + Water Chestnut —T_2	Fish + Water Hyacinth —T_3	Fish + Water Chestnut + Water Hyacinth—T_4
Water pH	1	6.8–7.1	6.4–7.1	6.4–7.0	5.9–6.9
Dissolved oxygen (ppm)	3	4.9–5.3	3.3–4.0	3.1–4.1	1.6–3.2
Temperature (C)	3	25.1–32.2	25.0–32.2	25.0–32.1	24.8–31.9
Total alkalinity (ppm)	4	66–74	57–63	54–63	46–58
DOM (ppm)		1.9–3.7	1.9–4.2	1.9–4.4	2.0–6.4
TSS (ppm)		187–321	181–245	197–243	185–229
Total plankton (nos. l^{-1})		5.9×10^3–4.6×10^4	2.9×10^3–4.6×10^3	2.4×10^3–2.8×10^3	3.9×10^2–2.2×10^3
Nitrite-N (ppm)	4	0.01–0.08	0.01–0.06	0.01–0.06	0.01–0.05
Nitrate-N (ppm)	4	0.17–0.49	0.16–0.4	0.17–0.39	0.16–0.39
Ammonia (ppm)	4	0.13–0.2	0.13–0.22	0.13–0.23	0.18–0.27

[1] DOM: dissolved organic matter; TSS: total suspended solids.
[2] Number refers to sources in the Sources of Materials section.

analyze *in situ* water pH[1] by calibrating the pH meter against a buffer solution at pH 4, 7, and 9.2; soil pH[2], and dissolved oxygen[3].

Apparent feed conversion ratio was calculated as dry weight of total feed given in kilograms/harvested biomass of fish in kilograms, and was estimated for each replication. To evaluate production performance, a production-size index (production in kg $ha^{-1} \times$ average weight in g $1{,}000^{-1}$) and a performance index (PI) (Mohanty 2004) were estimated. Treatment-wise gut contents analysis, including the frequency (average percentage of analyzed fish in which a different food component was found) and abundance (percentage of individual gut content volume) of cultured fish species (Spataru et al. 1983), was also carried out, once on the 45th day of rearing and again after harvesting, during first and second crop experiments, respectively. Economic indices of water productivity (WP; Mohanty et al. 2009) were estimated, taking the total volume of water used into account (water contained in the harvested biomass + evaporation + deep percolation and seepage + average standing water volume + volume of water added from other source) as follows:

$$\text{WP} = \text{Total value of the produce (Rs)} \\ - \text{production cost (Rs)/Volume of water used } (\text{m}^3)$$

The statistical analysis for standard error of the treatment means and least significant difference were calculated following Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Water quality

The recorded minimum and maximum values of various water quality parameters (Table 1) during the experimental period were as follows: water temperature, 24.8 to 32.2 C; water pH, 5.9 to 7.1; dissolved oxygen, 1.6 to 5.3 ppmv; total alkalinity, 46 to 74 ppmv; dissolved organic matter, 1.9 to 6.4 ppmv; nitrite-N 0.01 to 0.08 ppmv; nitrate-N, 0.16 to 0.49 ppmv; ammonia, 0.13 to 0.27 ppmv; total suspended solids, 185 to 321 ppmv; depth of water, 50 to 120 cm; and total plankton count, 3.9×10^2 to 4.6×10^4 L^{-1}. The pH of water body, total alkalinity, and dissolved oxygen concentration showed a decreasing trend as the rearing period progressed, while increasing trend of nitrite, nitrate, ammonia, and organic load were recorded toward the latter part of the experiment. The decreasing trend of dissolved oxygen in all the treatments in the presence of fish was mainly due to the gradual increase in surface cover and vegetative decomposition, resulting in higher oxygen consumption. Furthermore, decomposition of organic matter (feed) that requires additional oxygen, fluctuation in plankton density, and a gradual increase in biomass resulted in higher oxygen consumption (Mohanty 2010).

Gradual increase in nitrite, nitrate, and ammonia in all the treatments was attributed to intermittent fertilization, increased level of metabolites, and decomposition of plant material and/or unutilized feed in absence of water replenishment. At any given point in time, other water quality parameters and plankton population did not register any specific trend between the treatments, probably due to similar levels of input in all the treatments. Phytoplankton population was dominated mainly by diatoms and green algae (53%), whereas zooplankton population was dominated by copepods and rotifers (67%). In all the treatments, average primary production in the first month of rearing ranged between 133.5 ± 36.4 mg C m^{-3} h^{-1}, which deteriorated further (58.3 to 107 mg C m^{-3} h^{-1}) with the advancement of the rearing period. This low primary production was probably due to fixation of nutrient ions by suspended particles as well as rich organic matter. In general, poor growth performance of cultured species takes place at pH < 6.5 (Mount 1973), whereas higher values of total alkalinity (> 90 ppmv) indicate a better productive ecosystem. The availability of CO_2 for phytoplankton growth is related to total alkalinity, while water having 20 to 150 ppmv total alkalinity produces a suitable quantity of CO_2 to permit plankton production (Mohanty 2003). However, the recorded minimum and maximum values of total alkalinity during the experimental period were 46 and 74 ppmv, respectively, which were maintained due to periodic liming. Slightly higher values of the nitrogenous compounds and total alkalinity were recorded towards the latter part of the experiment. Gradual increase in the nitrogenous compounds could be attributed to intermittent fertilization, increased level of metabolites, and decomposition of biological materials in the absence of water replenishment (Mohanty et al. 2010) in the experiment.

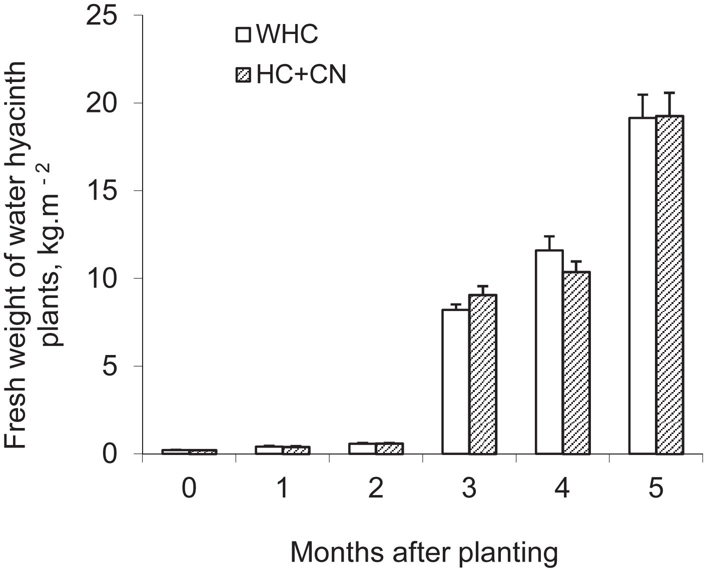

Figure 1. Changes in fresh weight of waterhyacinth (kg m^{-2}) at monthly intervals grown either alone (WHC) or in combination with water chestnut (HC + CN). Each value is the mean of three replications. Vertical bars represent ± SE of mean.

Growth of water chestnut

When water chestnut and waterhyacinth were allowed to grow independently during the initial period, up to the second MAP, growth of waterhyacinth was slower compared to the growth of water chestnut. During the first 60 d, waterhyacinth biomass grew 5.83 g m^{-2} d^{-1}, whereas water chestnut grew 9.66 g m^{-2} d^{-1}. However, the growth of water chestnut declined marginally to 7.83 g m^{-2} d^{-1} in the presence of waterhyacinth. Overall growth of waterhyacinth did not change significantly in the presence of water chestnut (Figure 1). But in presence of waterhyacinth, the growth of water chestnut showed a significant decrease especially after the second MAP (Figure 2). From mid-September, waterhyacinth smothered growth of water chestnut, affecting the growth of the plant. During the period waterhyacinth grew exponentially 206 g fresh weight m^{-2} d^{-1} and competing with growth of waterhyacinth, the water chestnut grew 164 g fresh weight m^{-2} d^{-1} until mid-September as a sole crop. But in presence of waterhyacinth, growth of water chestnut was suppressed and it grew 47 g m^{-2} d^{-1} during the same period (Figures 1 and 2). Similarly, the dry matter production rate or crop growth rate of waterhyacinth was not affected significantly in presence of water chestnut in comparison to dry matter production rate of sole crop of waterhyacinth except at 4 MAP, when presence of water chestnut retarded the growth rate of waterhyacinth by 50% (Figure 3). But dry matter production rate of water chestnut plants decreased significantly in the presence of waterhyacinth from initial stage of crop growth itself. At 2 MAP, the decrease was 37% and the extent of decline at 4 MAP reached to 80% and at fifth-month stage the rate of dry matter production of water chestnut plants in the presence of waterhyacinth was almost negligible. At 4 and 5 MAP the decline in dry matter by water chestnut plants in presence of waterhyacinth was 69 and 67% compared to that of a sole crop of water chestnut.

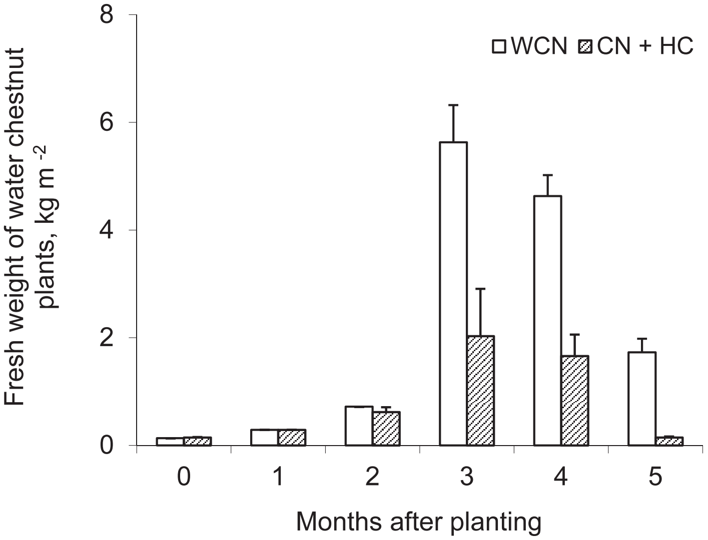

Figure 2. Changes in fresh weight of water chestnut plants (kg m^{-2}) at monthly intervals grown either alone (WCN) or in combination with waterhyacinth (CN + HC). Each value is the mean of three replications. Vertical bars represent ± SE of mean.

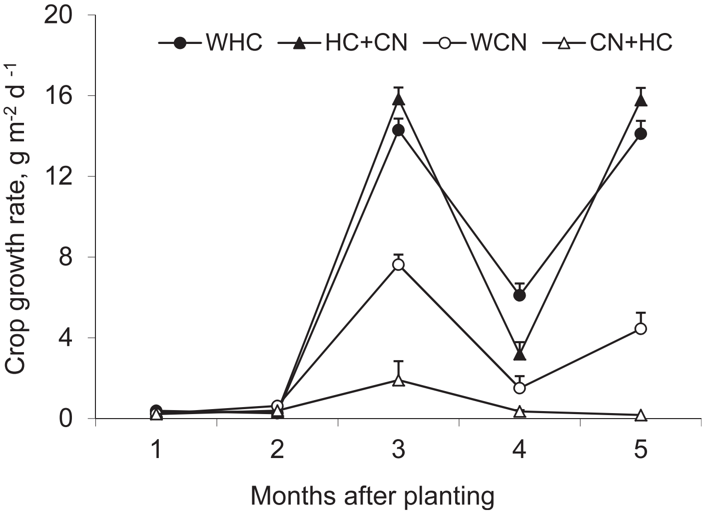

Figure 3. Changes in rate of dry matter production (crop growth rate, g m^{-2} d^{-1}) of waterhyacinth grown either alone (WHC) or in combination with water chestnut (HC + CN) and of water chestnut grown either alone (WCN) or in combination with waterhyacinth (CN + HC) at monthly intervals. Vertical bars represent ± SE of mean.

Mature leaves in the floating leaf crowns are the main functional leaves for photosynthesis in water chestnut (Roy Chowdhury et al. 2002). Leaf area attained its peak both in green and red water chestnut cultivars at 3 MAP before showing decline in subsequent months (Figures 4 and 5). The development leaf area in a sole water chestnut crop (Figures 4 and 5) showed that the green-type water chestnut cultivars maintained higher leaf area for a longer duration compared to red cultivars. However, waterhyacinth retarded the spread of canopy in both types. The extent of

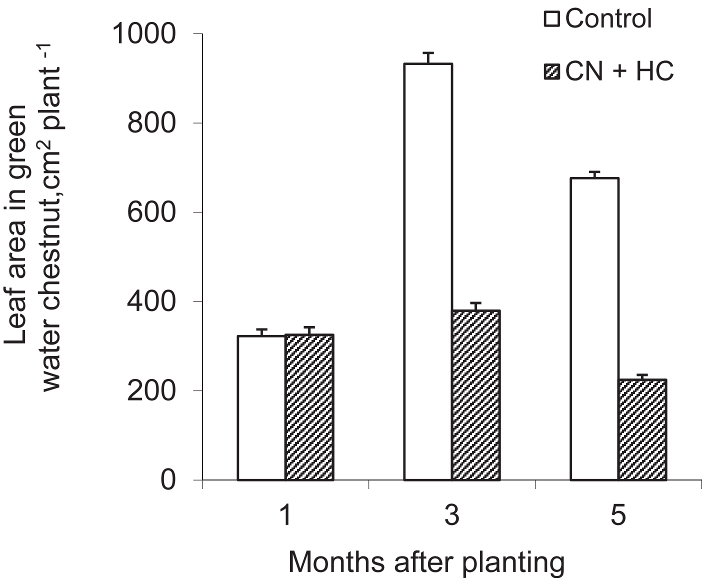

Figure 4. Changes in leaf area of water chestnut (green-peeled cultivar; cm^2 plant^{-1}) at monthly intervals grown either alone (control) or in combination with waterhyacinth (CN + HC). Each value is the mean of three replications. Vertical bars represent ± SE of mean.

decrease was 59% at 3 MAP in green type, which increased to 66% at 5 MAP. The decrease in canopy area in red type during corresponding period was 45 and 30%, respectively. This further suggested competitive dominance of waterhyacinth smothering spread of water chestnut canopy, leading to poor growth and dry matter production by water chestnut plants. Canopy development of the green cultivar suffered more than the red cultivar in the presence of waterhyacinth. The red water chestnut cultivars managed to show lesser decrease at later stage (5 MAP) as they tended to maintain leaf area for longer duration than green cultivars (Roy Chowdhury et al. 2003). However, both red and green cultivars exhibited identical trend of reduction in leaf area in the presence of waterhyacinth. In general, flowering started in green cultivars 7 to 10 d earlier than flowering in red cultivars under experimental conditions. Correspondingly, fruits also appeared 7 to 10 d later in red cultivars. From 3 MAP onward, the number of flowers per plant (Figure 6) showed a consistent decline in presence of waterhyacinth. The extent of decrease was more in green fruits at 4 MAP than in red fruits. Red-pigmented plants flowered and fruited later than green-pigmented plants, and the decline in flower number in red-pigmented plants was apparent at later stages of crop growth (5 MAP). At 6 MAP flowering ceased both in red as well as in green cultivars. A similar trend was noted in the appearance of fruits as well as number of fruits per plant, which severely declined in presence of waterhyacinth (Figure 7). The magnitude of decrease was greater in green than in red cultivars. In fact, the green cultivars were not only higher yielding than red ones, but also earlier producing due to early-flowering behavior (Roy Chowdhury et al. 2003). Apart from the effect on frequency of flowering and fruit number, the development of fruits was also affected by presence of waterhyacinth. Size of fruits decreased by about 60% in plots where water chestnut and waterhyacinth were grown together (Figure 8). The color of fruit was pale and less pigmented, rendering the fruit unattractive. Average yield of a sole water chestnut crop was 3.97 t ha^{-1} and yield

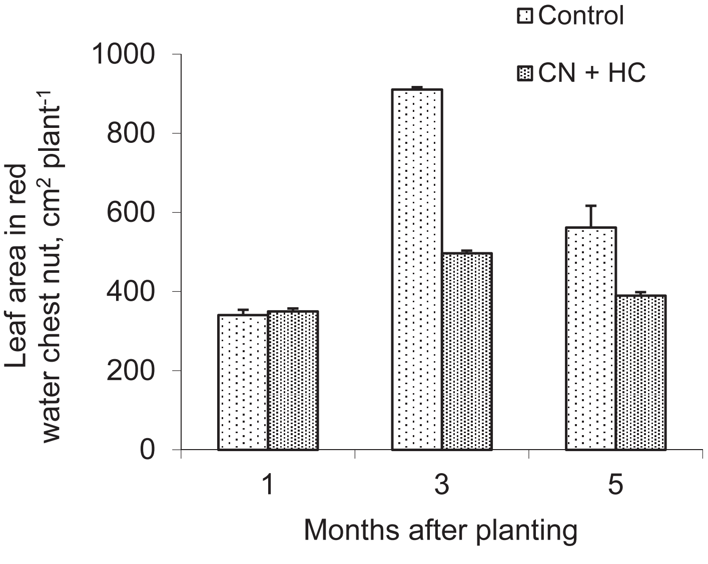

Figure 5. Changes in leaf area of water chestnut (red-peeled cultivar; cm^2 plant^{-1}) at monthly intervals grown either alone (control) or in combination with waterhyacinth (CN + HC). Each value is the mean of three replications. Vertical bars represent ± SE of mean.

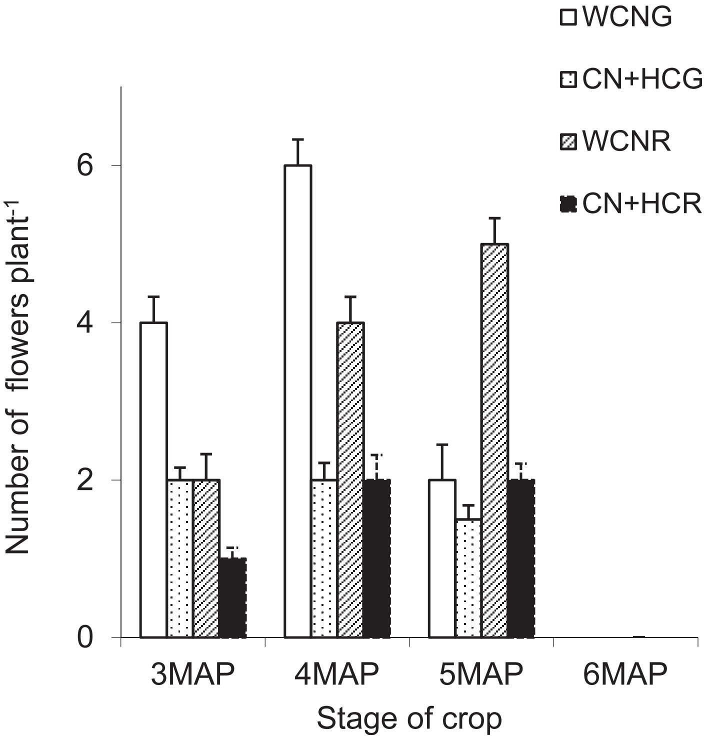

Figure 6. Changes in the number of flowers per plant of water chestnut, green-peeled (G) and red-peeled (R) cultivars, at monthly intervals grown either alone (WCNG, WCNR) or in combination with waterhyacinth (CN + HCG, CN + HCR), respectively. Each value is the mean of three replications. Vertical bars represent ± SE of mean. MAP: months after planting.

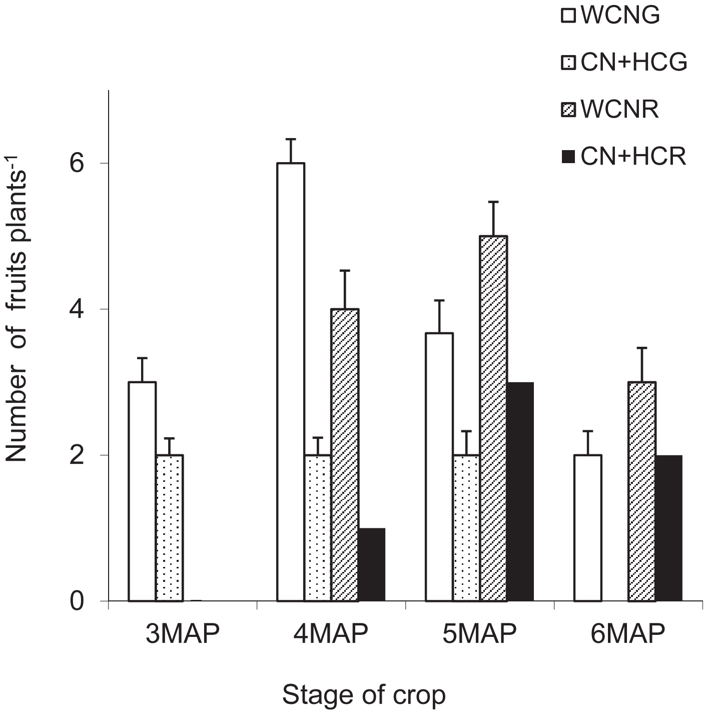

Figure 7. Changes in the number of fruits per plant of water chestnut, green-peeled (G) and red-peeled (R) cultivars, at monthly intervals grown either alone (WCNG, WCNR) or in combination with waterhyacinth (CN + HCG, CN + HCR). Each value is the mean of three replications. Vertical bars represent ± SE of mean.

declined to 0.25 t ha^{-1} when it was grown in combination with waterhyacinth. The poor growth of the water chestnut crop in the presence of waterhyacinth led to fewer flowers, fewer fruit sets, and weaker fruit filling. All these factors might have contributed to such drastic yield reduction in water chestnut plants when grown in combination with waterhyacinth.

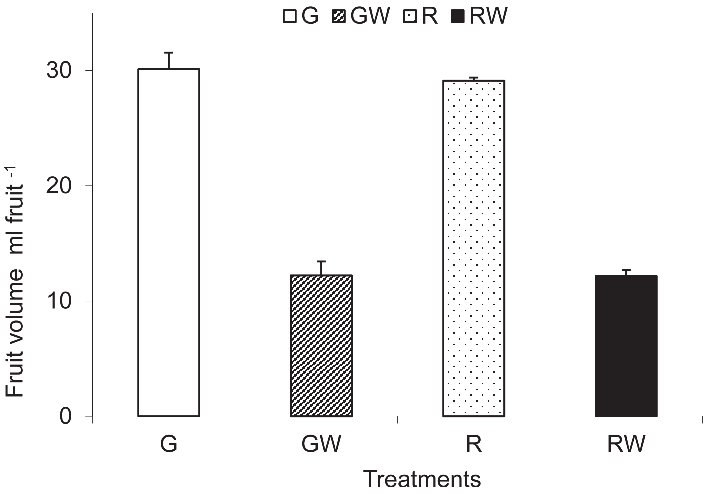

Figure 8. Changes in the volume of fruit of green-peeled and red-peeled water chestnut cultivars (ml $fruit^{-1}$) at monthly intervals grown either alone (WCNG, WCNR) or in combination with waterhyacinth (CN + HCG, CN + HCR). Each value is the mean of three replications. Vertical bars represent ± SE of mean.

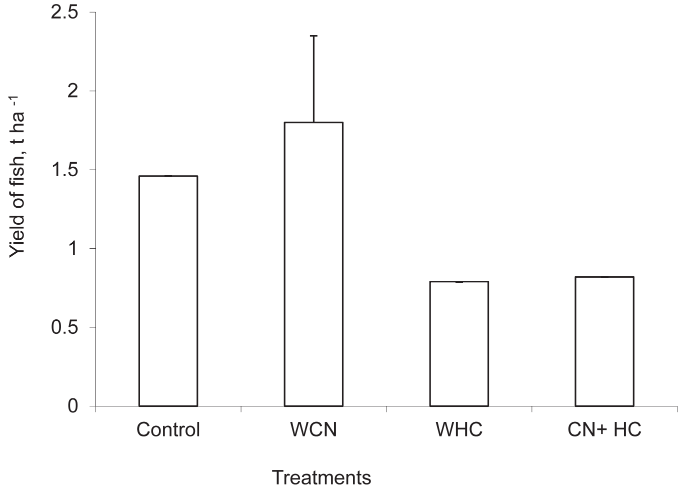

Figure 9. The total yield of fish (t ha^{-1}) grown either alone (control) or in combination with water chestnut (WCN) or with waterhyacinth (WHC) and in combination with both (CN + HC). Each value is the mean of three replications. Vertical bars represent LSD at $P = 0.05$.

Growth of fish

When fingerlings (16.5 g MBW; 7,500 fish ha^{-1}) of walking catfish were reared, highest average growth (360 g MBW) was obtained when fish were reared with water chestnut, followed by control (282.5 g MBW), fish + waterhyacinth (237.9 g MBW), and fish + water chestnut + waterhyacinth (224.5 g MBW). Treatment-wise average survival rate was 68.1, 68.1, 48.8, and 44.4% in control (fish only), fish + water chestnut, fish + waterhyacinth, and fish + water chestnut + waterhyacinth, respectively. The lower survival and growth rate in fish + waterhyacinth and fish + waterhyacinth + water chestnut systems was probably due to competition for space and nutrients, very low primary productivity (58.3 to 98.8 mg C m^{-3} h^{-1}), and low intensity of light penetration. Fish yield (Figure 9) was highest in combination with water chestnut (1.8 t ha^{-1}), which was higher than the control (fish only; 1.46 t ha^{-1}). Fish yield in terms of production (t ha^{-1} in 120 d) in fish + water chestnut treatment was, however, significantly higher ($P < 0.05$) than yield in fish + waterhyacinth and fish + water chestnut + waterhyacinth. However, there was no significant variation between yields with fish only and fish + water chestnut. Fish yield significantly declined in presence of either only waterhyacinth (0.79 t ha^{-1}) or in the combined presence of water chestnut and waterhyacinth (0.82 t ha^{-1}). Growth is the manifestation of the net outcome of energy gains and losses within a framework of abiotic and biotic conditions. In this experiment, existence impact of waterhyacinth on production PI of fish was highly significant ($P < 0.05$), while there was no significant variation among PI in presence of water chestnut. Due to higher yield, production size index (648) and PI (194.9) of walking catfish culture along with water chestnut appeared promising. This indicates the possibility of integrated farming of fish and water chestnut, where fish gets sufficient natural food and growth remains unaffected. Observations on apparent feed conversion ratio (AFCR)

Table 2. Average percentage of individual gut contents volume (abundance) and percentage of analyzed species in which mentioned food components were found (frequency) in fish + water chestnut system.

Food component	Abundance[1] (%)	Frequency (%)
Supplemental feed	46.1^{+}	88.8
Phytoplankton	2.7^{-}	66.6
Zooplankton	1.9^{-}	72.2
Aquatic insects	32.1^{+}	88.9
Detritus + benthos	12.2^{-}	55.6

[1]+ More than; – less than.

also support the conclusion of effective utilization of ecological niches, as AFCR ranged between 1.09 and 1.39.

The gut contents analysis reveals omnivorous feeding behavior (Table 2), and the food item consumed in greatest quantity was artificial supplemental feed (46.1%) followed by aquatic insects (32.1%) and detritus + benthos (12.2%). Fish preferred by 32.4 ± 5.8% natural food from the ecosystem even in the presence of supplemental food. Thus, under controlled conditions 25 to 30% feed could be reduced during each meal. Frequency distribution of available food items in the gut contents of the cultured fish indicated plentiful availability of aquatic insects, periphytic algae, and benthic organisms that helped to reduce the supplemental feed input. Estimated degree of satiation (index of gut fullness) at fingerling stage was high, indicating a distinct declining trend from fingerling stage to advanced fingerling stage, probably due to relatively low nutritional value of the ingested matter (mud and debris) and comparatively less preference for artificial feed at the initial stage of rearing.

Water productivity

The economic indices of different systems expressed as gross water productivity (Mohanty et al. 2009) from fish only was found out to be Rs 7.3 m^{-3}, whereas in combination of fish and water chestnut the gross water productivity was Rs 14.67 m^{-3}. The gross water productivity of the plot where fish was grown in presence of waterhyacinth was found to be Rs 3.95 m^{-3} and in the system where fish, water chestnut, and waterhyacinth were grown together, the gross water productivity was found to be Rs 4.45 m^{-3}.

Conclusions

The comparative growth behavior of water chestnut and waterhyacinth revealed that initial rapid growth of water chestnut smothered the spread of waterhyacinth. However, at later stages of growth waterhyacinth suppressed growth of water chestnut, especially at the time of flowering. This coincidence with reproductive phase of water chestnut affected both flowering and fruit development, resulting in a reduction of yield of water chestnut. Growth of fish was appreciably higher in combination with water chestnut cultivation compared to a combination with waterhyacinth or without any vegetation (i.e., control). Under such conditions, 25 to 30% of the supplemental fish feed could be replaced with natural feed from the growth environment. The combined cultivation of the fish–water chestnut system produced about 3.97 t ha^{-1} water chestnut with 1.8 t ha^{-1} of catfish in 120 d. Coproduction of fish with water chestnut is not practiced widely, because of anticipation of water quality and growth-related problems. However, in the present experiment, it was found that despite marginal deterioration of water quality parameters, successful rearing of walking catfish with water chestnut was not only possible but also had the potential to enhance the overall yield, water productivity, reciprocal advantage, and efficient utilization of the ecosystem. Hence, water chestnut and catfish cultivation provides a good alternative for utilization of shallow waterlogged areas for better productivity.

SOURCES OF MATERIALS

[1]Checker-1, HANNA Instruments, Rhode Island, 270 George Washington Highway, Smithfield, RI 02917.

[2]DM13, Takemura Electric Works Ltd. 2-29-11, Nishi-Ikebukuro, Toshima Ku, Tokyo, Japan, 171-0021

[3]YSI 55, YSI Incorporated, 1700/1725 Brannum Lane, Yellow Springs, OH 45387 USA

[4]FF-1A. Hach Company, P.O. Box 389, Loveland, Colorado 80539

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