Phenological episodes of *Myriophyllum spicatum* (Haloragaceae); a highly invasive species in Kashmir Himalayan aquatic ecosystems.

Shahzada Arshid* and Aijaz A Wani**

Cytogenetics and Reproductive Biology Laboratory, Department of Botany, University of Kashmir, Hazratbal Srinagar-190 006, India.
*shahzada194@gmail.com; **aijazbotku@gmail.com

Abstract: Phenological behaviour of *Myriophyllum spicatum*, a highly invasive species in Kashmir Himalayan aquatic ecosystems, was studied in different standing and running water populations for a period of 12 months to monitor the various developmental stages. The plant starts its life cycle with the sprouting of rhizomes and axillary buds in standing water populations, whereas in running waters rhizomes and nodal plantlets contribute to new recruitments. In standing waters flowering phase prolongs when compared to running water populations. In standing water populations a high seed set was observed, whereas in running waters seed formation does not take place. The knowledge of time period and formation of these vegetative and sexual propagules by this invasive species is very important for its effective management and control in these ecosystems.
[Shahzada Arshid and Aijaz A Wani. **Phenological episodes of *Myriophyllum spicatum* (Haloragaceae); a highly invasive species in Kashmir Himalayan aquatic ecosystems.** Nature and Science 2011;9(5):42-45]. (ISSN: 1545-0740). http://www.sciencepub.net.

Keywords: *Myriophyllum spicatum*; phenology; Kashmir Himalaya; Propagules; management.

Introduction

Many factors affect the reproductive success of flowering plants. Among these factors, the timing, frequency and duration of the flowering period collectively referred to as phenology is obviously of great importance (Rathcke and Lacey, 1985). The phenology of a species not only encompasses when, how often, and how long reproduction takes place but also determines the degree of reproduction synchrony with other plant species . Synchrony among species might be advantageous if the presence of one species facilitates increase in pollinator visitation and thus fruit/seed set in another species (Rathcke and Lacey, 1985). Phenology in general and reproductive phenology in particular is a critical and important trait of a plant because it determines the growth, developmental pattern and number of potential mates in a population thus providing a mechanism for reproductive isolation or speciation over time (Rathcke, 1983; Bronstein *et al.*, 1990). Researchers always and continuously try to identify environmental factors that correlate with phenological events such as initiation of flowering, the synchronization of flowering, the length of the flowering phase and variation in flower abundance (Opler *et al.*, 1980; Borchert, 1983; Inouye *et al.*, 2002). Environmental factors that initiate the onset of a particular phenophase include photoperiod, temperature and precipitation (Rathcke and Lacey, 1985). The same environmental factors can delimit a particular phenophase including flowering season in some specific ecoedaphic conditions or environments (Borchert, 1980; Inouye and McGuire, 1991).

The *Myriophyllum*, commonly known as watermilfoil, is among the species rich (68 spp.) genus of the aquatic "Core eudicots" (APGII, 2003). It shows a cosmopolitan distribution (except Antarctica), with a centre of diversity in Australia (42 spp., 34 endemic), North America (14 spp., 7 endemic) and Asia (16 spp., 8 endemic) also harbor a significant continental diversity and share seven common species . (Moody and Les, 2010). *Myriophyllum* is well-known for its invasive species. The aggressive *M. spicatum* L. (Eurasian watermilfoil) has now established on most continents and listed as noxious weeds in United States. Hybridization also has been shown to play a role in North American invasions with two hybrid lineages recognized which are *M. spicatum* x *M. sibiricum* and *M. heterophyllum* x *M. laxum* (Moody and Les, 2002*)*.

From the Indian subcontinent, five species of *Myriophyllum* have been reported (Hooker, 1879). In the Kashmir Himalaya, earlier the genus has been reported to comprise of two species: *M. spicatum* and *M. verticillatum* (Kaul and Zutshi, 1965), while as later on three species have been reported viz. *M. spicatum, M. verticillatum* and *M. tuberculatum* (Kak, 1990).

M. spicatum is native to Europe, Asia and North America (Couch and Nelson, 1985). It was introduced into North America between 1880's and 1940's and now occurs in both Canada and the United States (Reed, 1977, Couch and Nelson, 1985, Aiken *et al.*, 1979). From the initial point of introduction in the North America, *M. spicatum* has spread to 44 states and at least three Canadian provinces (Creed, 1998) and is now considered a major nuisance species throughout the Northeast, Northern Midwest and Pacific Northwest of

the United States (Couch and Nelsons, 1985; White *et al.*, 1993). *M. spicatum* has spread to 46 states and three Canadian provinces of North America (Jacono and Richerson, 2003; Kim, 2005). *M.spicatum* is categorized among the five most noxious wetland plants and it is the most widely managed aquatic need in the United States (Bartodziej and Ludlow, 1998). The knowledge about phenology of invasive plants is very important for their effective management and can be utilized to identify week points in their life cycle and long term management.The present study was undertaken with the same objective.

Materials and Methods

Healthy individuals of the species were selected from different standing and running water populations, tagged and examined throughout the growing season to study the life history pattern and mode of reproduction operative in the species in relation to habitat condition of the study sites. The tagged individuals were monitored to record data on various reproductive phenophases such as initiation of budding,vegetative growth, peduncle growth and anthesis, duration of flowering and seed formation. The axillary bud formation was examined regularly and their number was recorded to evaluate the importance of these propagules in the reproduction and fitness of the species.

Results:

The species is a submerged, perennial herb with pinnately divided leaves inhabiting both standing and running water habitats. The phenological behaviour of the species was studied in both standing and running water populations. The phenology starts with the sprouting of rhizomes and axillary buds in the first week of March and continues upto first week of April in standing water populations, whereas sprouting of rhizomes and formation of nodal plantlets commences in the second week of March and continues upto second week of April in running water populations. The planlets grow vegetatively from second week of April upto first week of June in standing waters, while in running waters the process is completed between second week of April and second week of July. The mature plantlets enter into the sexual phase during first week of June and flowering continues upto last week of September in standing waters. However, in running waters this phase starts during fourth week of June and lasts upto third week of September. In standing waters fruiting sets from second week of September and ends in third week of October. In running waters however fruits are not formed. The senescence of the above sediment parts starts in the second week of October and continues till first week of December in standing water and in running waters the process starts during the fourth week of October and continues upto the last week of December (Table 1 and Figure 1).

Table 1. Phenological behavior of *Myriophyllum spicatum* in standing and running water populations in the Kashmir Himalaya.

Phenophase	Habitat	Duration	Number of days
Sprouting of vegetative propagules(rhizomes,axillary buds, nodal planlets)	SW RW	1 * (3) ** - 1 (4) 2 (3) - 2 (4)	27 32
Vegetative growth	SW RW	2 (4) - 1 (6) 2 (4) - 2 (7)	62 88
Flowering phase	SW RW	1(6) - 4 (9) 4(6) - 3(9)	110 81
Fruiting phase	SW RW	2 (9) - 3(10) -	39 -
Senescence	SW RW	2 (10) - 1(12) 4 (10) - 4(12)	54 60

SW = Standing water
RW = Running water
* = Week
( ) ** = Month

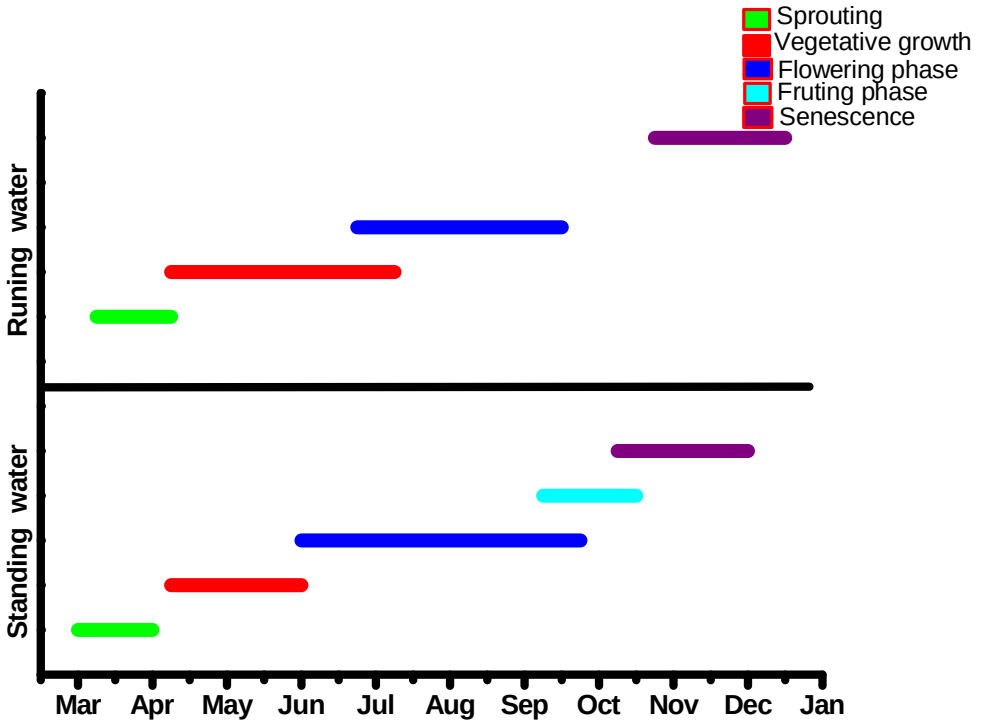

Figure 1: Phenological behaviour of Myriophyllum spicatum in different standing and running water populations.

Discussion

Myriophyllum spicatum overwinters by means of rhizomes and winter buds. These structures start sprouting during the first week of March and continue upto second week of April when environmental conditions such as temperature and light are available, because these factors are important for the initiation of a particular phenophase (Rathcke and Lacey, 1985). The vegetative growth commences during April and continues till June; however in running water populations the vegetative growth phase is longer than in standing water populations. The flowering commences from June to September and continues for 1-4 months in standing water populations and for 1-3 months in running water populations. The longer vegetative phase, delayed and shorter flowering phase in running waters may be due to the lower allocation of resources to sexual reproduction and permanent exposure of plants to mechanical stress (Niklas, 1998; Henery and Thomas, 2002; and Hodges *et al.*, 2004). The fruiting phase completes from September to October in standing water populations where as in running water populations fruits are not formed. The senescence starts from second week of October and continues till December. These phenological events are in agreement with the work of Patten (1956) and Spencer and Lekic (1974).*M. spicatum* produces flowers, seeds and axillary buds during June-October. Therefore removal of ramets before June can prove an effective method for control of this aggressive species. This is supported by the work of Caffery and Monahan (2006) who reported that in *Myriophyllum verticillatum*, removal of turions yielded desirable results in control of this species as compared to annual treatment with dichlobexil, followed by mechanical cutting. The present study revealed that knowledge about various life history traits, such as different types of sexual and vegetative propagules, their time of formation and germination is very important for long term management of this aggressive species in the Kashmir Himalayan aquatic ecosystems.

Acknowledgement: The authors wish to thank Head Deptt. Of Botany for providing the laboratory facilities and CSIR New Delhi for financial assistance in the form of JRF to Shahzada Arshid.

Corresponding author:
Shahzada194@ gmail.com.

References

1. Aiken, S. G., Newroth, P. R. and Wile, I. The biology of Canadian weeds. 34-*Myriophyllum spicatum L. Candian Journal of Plant Science.* 1979;**59:** 201-215.
2. Angiosperm Phylogeny group (APG) II. An updated classification of the angiosperms. *Botanical Journal of Linnaean Society*. 2003;**141:**399-436.
3. Bartodziej, W. and Ludlow, L. Aquatic vegetation monitoring by natural resource agencies in the United States. *Aquatics.* 1998;**20:** 15-18.
4. Borchert, R. Phenology and ecophysciology of tropical trees: *Erythrina poeppigiana* Cook. *Ecology*.1980; **61:** 1065-1074.
5. Borchert, R. Phenology and Control of flowering in tropical trees. *Biotropica*. 1983;**15:** 81-89.
6. Bronstein, J. L., Gouyon, P.H., Gliddon, C., Kjellberg, F. and Michaloud, G . The Ecological consequences of flowering asynchrony in monoecious fogs: A simulation study. *Ecology*. 1990;**71**: 2145-2156.
7. Caffrey, J. M., Monahan, C. Control of *Myriophyllum verticillatum* L. in Irish cannals by turion removal. *Hydrobiologia*.2006; **570:** 211-215.
8. Couch, R. and Nelson, E. *Myriophyllum spicatum* in North America. Proc. 1st International symposium on watrmilfoil (*Myriophyllum spicatum)* and related Haloragaceae species. *Aquatic Plant Manage. Soc*.1985; pp. 8-18.
9. Creed, R. P. A biogeographic perspective on Eurasian watermilfoil declines: additional evidence for the role of herbivorous weevils in promoting declines. *J. Aquatic Plant Manage*. 1998;**36**: 16-22.
10. Henry, H. A. L. and Thomas, S. C. Interactive effects of shade and wind on stem, allometry, biomass allocation and mechanical stability in *Abutilon theophrasti* (Malvaceae). *American Journal of Botany*. 2002;**89:** 1609-1615.
11. Hodges, L., Suratman, M. N., Brandle, J. R. and Hubbage, K. G. Growth and yield of Snap beans as affected by wind protection and microclimate changes due to shelter-belts and planting dates. *Hort. Science*. 2004;**39:** 996-1004.
12. Hooker, J. D. The flora of British India Vol. II. L. Reeve and Co. Ltd., London.1879; Pp, 432-434.
13. Inouye, D. W., Morales.M and Dodge, G. Variation in timing and abundance in flowering by *Delphinium barbeyi* Huth (Rananculaceae). The role of snowpeak, frost in the context of climate change. *Oecologia* 2002;139: 453-550.
14. Inouyl, D. W and McGure, A.D . Effects of snowpeak on timing and abudndance of flowering in *Delphenium nelsonii* (Rananculaceae): implications for climate change. *Am. J. Bot.* 1991;**78:** 997-1001.
15. Jacono, C. C. and Richerson, M. M. Aquatic and wetland plants of northeastern North America. Vol. I.2003. The University of Wisconsin Press, Madison, Wisconsin.
16. Kak, A. M. Aquatic and wetland vegetation of the Kashmir Himalaya. *Jour. Econ. Taxon. Bot.* 1990;**14:** 1-14.
17. Kaul, V and Zutshi, D. P. A study of aquatic and marshland vegetation of Srinagar lakes. *Proc. Nat. Inst. Sci. Ind.* 1967;**33**: 111-127.
18. Kim, A. S. (2005). Milfoil Campaign spreading. Portland Press Herald.
19. Moody, M. L. and Les, D. H. Evidence of hybridity in invasive watermilfoil (*Myriophylllum*) populations. *Proceedings of the National Academy of Sciences of United States of America*, 2002;**99:** 14867-14871.
20. Moody, M. L. and Les, D. H. Systematic of aquatic angiosperms genus *Myriophyllum* (Haloragaceae). *Syst. Bot.* 2010;**35:** 121-139
21. Niklas, K. J. Effect of variation on mechanical properties and biomass allocation pattern of *Capsella bursa-pastoris* (Cruciferae). *Annals of Botany.* 1998;**82:** 147-156.
22. Opler, P. A., Franke, G.W and Baker, H. G. Comparative phenological studies of treelet and shrub species in tropical wet and dry forests in the lowlands of Costa Rica. *J. Ecol.* 1980**;68:** 167-188.
23. Patten, B. C. Jr. Notes on the biology of *Myriophyllum spicatum* in a New Jersey Lake. *Bull. Torr. Bot. Club*. 1956;**83**: 5-18.
24. Rathcke, B. Competition and facilitation among plants for pollination. In: Pollination Biology. Real, L. (Ed), Academic Press, Orlando, Florida, USA,1983; pp: 305-329.
25. Ratheke, B. and Lacey, E. D. Phenological patterns of terrestrial plants. *Annual Review of Ecology and systematic*. 1985;**16:** 179-214
26. Reed, C. F. History and disturbance of Eurasian watermilfoil in united states and Canada. *Phytologia.* 1977;**36:** 417-436.
27. Spencer, N. R. and Leikic, M. Prospects for biological control of Eurasian watermilfoil .*Weed Science*.1974; **22**: 401-404.
28. 28.White, D. J., Haber, E. and Keddy, C. (1993). Invasive plants of natural habitats in Canada. Canadian wildlife service, Environment Cannada, Ottawa, Ontario.

3/17/2011