

STARVATION RESISTANCE FOR FRUCTOSE SUGAR IN THREE INDIAN SPECIES OF THE GENUS-*DROSOPHILA*

Arun Kumar*
Dr. Ajai Kumar**

ABSTRACT

During present investigation, starvation resistance of isofemale line from different natural populations of three closely related Indian species of *bipunctinata*-sub group of the genus-*Drosophila* have been undertaken in presence of fructose sugar in culture media. The species were *Drosophila malerkotiana*, *Drosophila bipunctinata* and *Drosophila parabipunctinata*. The F1 individuals from each isofemale line were placed under starvation condition in vials. Survival time in fructose sugar media was recorded for each male in the vial. Variations in resistance for starvation in inter-population studies were analyzed by student t-test. In certain comparison, significant differences were observed in starvation tolerance among different *Drosophila* species under observations. The paper discusses about the genetic basis for such a significant variation in resistance to starvation.

Key words: *bipunctinata* subgroup, *Drosophila*, Fructose, inter-population, Starvation resistance, survival time,

Introduction

The genetics of complex adaptation, particularly the degree to which populations follow either parallel or divergent evolutionary trajectories under common selective pressures is an area of active interest in evolutionary biology (Gompel and Prud'homme, 2009; Stern and Orgogozo, 2009). Desiccation resistance in *Drosophila* is an interesting choice for its complex trait in which the study of repeated patterns of evolution among species and populations can throw fresh insight on the correlation between ecology and physiology. Many *Drosophila* encounter periods of low humidity during their life-history and must balance water content against integument water loss owing to a high surface area/volume ratio. In doing so, numerous *Drosophila* species have successfully colonized arid habitats including deserts and high altitudes as well as tropical and temperate zones, providing an excellent model to study adaptation to desiccation at the intra- and inter-population level (Gibbs, 2002; Parkash et al., 2005). By contrast several rainforest restricted species show little ability to evolve resistance little ability to evolve resistance to desiccation (Hoffmann et al., 2003; Kellermann et al., 2009), although they show ample genetic variation for many other traits. Little is known about the mechanisms underlying natural genetic variation for desiccation survival in *Drosophila* at the population scale, and it is difficult to ascertain why some species adapt easily whereas others are limited by low adaptive variation for desiccation stress.

To date, most studies on the evolution of desiccation resistance have focused on populations derived from experimental evolution, with emphasis on the physiological, correlated and life-history responses

*Arun Kumar is a Research Scholar, Feroze Gandhi College Raebareli 229001, India. Email- arun_nsps@yahoo.com

** Dr. Ajai Kumar is Head & Associate Professor, Genetics & Molecular Biology Laboratory, Department of Zoology, Feroze Gandhi College Raebareli- 229001. Email: ajaikumar_rbl2002@yahoo.com

associated with increased desiccation (Hoffmann and Harshman 1999; Telonis-Scott et al., 2006). Comparative physiology among different *D. melanogaster* lines suggests that multiple evolutionary solutions can arise from a common selection pressure, although reducing water loss by water retention is a common mechanism underlying survival to desiccation (Gibbs et al., 1997; Hoffmann and Harshman, 1999; Gibbs, 2002; Telonis-Scott et al., 2006). Although artificial selection experiments are not without limitations, trait variation in natural populations may be inferred if enough alleles are sampled from the founding population. Signatures of natural selection for desiccation resistance are also evidenced in latitudinal clines, where survival can vary markedly among *Drosophila* according to local climatic conditions. Substantial variation in survival between populations suggests local adaptation and the presence of ample genetic variation (Coyne et al., 1983; Blows and Hoffmann, 1993; Kristonson et al., 2011; Hoffmann et al., 2005). Opposing clines for desiccation and starvation resistance have been observed for seven Drosophilid species of the Indian subcontinent including *D. melanogaster*, where desiccation survival increased with latitude (Parkash et al., 1994; Karan and Parkash, 1998; Karan et al., 1998; Parkash and Munjal, 1999, Prakash, et.al 2011 (a) Parkash, et al.,2011 (b))

Genus - *Drosophila* is largest group of drosophilid flies comprising as many as six subgenera and many species groups. Among these groups the bipeptineta sub group of *melanogaster* species group is second largest one. It contains several example of sibling species (Parson,1987). The cytogenetics and population genetics of *bipeptineta* subgroup of the genus *Drosophila* have been widely investigated (Kumar et al., 2004; Panigrahy 1984; Gupta & Panigrahy 1990). Most common among sibling species of this subgroup are *Drosophila melanogaster*, *D.bipeptinata* and *D.parabipeptinata*. Due to their close morphological feature, sympatric nature, divergence in resource utilization for different fruit bits and different sugar in culture media, these species were selected for the present investigation for variation in intra and inter specific level of starvation resistance in fructose sugar media for baits first time.

Methods

The flies of three species of the *bipeptinata* subgroup of the genus- *Drosophila* viz. *Drosophila malerkotiana*, *Drosophila bipeptinata* and *Drosophila parabipeptinata* were collected during different seasons from different geographical localities of Raebareli and adjoining area by using fermented banana bait. The female individuals caught from these collections were reared on *Drosophila* food medium containing agar-sugar fructose -maize at $24^{\circ}\text{C} \pm 1^{\circ}\text{C}$ temperature to construct isofemale lines. Single female was kept in separate food vials. Only F1 males were compared in 10 randomly selected isofemale line to observe starvation tolerance in three *Drosophila* species under investigation, since both the sexes have similarity for tolerance at genetic level (Parson ,1983)

On emergence, the adults of *Drosophila* species were distributed in group of 10 male individuals. Each group was fed on same food medium for 72 hours and then placed in experimental capped plastic vials of 60 ml capacity without food. These vials contained a piece of foam sponge dipped in water saturated with nipagin to prevent bacterial infection. Relative humidity was observed to be 100%. Duplicate set of all the vials were prepared during this experiment to avoid any error in the observations. Experiments were performed at 24°C . After setting up the experiments, each vial was observed at an interval of one hour and number of dead individuals was recorded

Result

During present study three *Drosophila* species belonging to *bipeptinata*-subgroup were collected from different geographical regions of UP of India in different seasons. The average number of flies collected in different seasons was much higher for *Drosophila malerkotiana*, as compared to *Drosophila bipeptinata* and

lowest for *Drosophila parabiopectinata*. The survival time for each individual male under starvation conditions has been recorded in all the three species of *Drosophila* under investigation (**Table 1**). The data show variation in resistance to starvation among individual of isofemale line despite being reared from a single female. The mean survival time varies at inter population level from 36.5 ± 1.59 to 57.8 ± 2.88 . The mean survival time also varies at intra-specific level e.g. in *Drosophila malerkotiana* it ranges between 43.5 ± 2.26 to 57.8 ± 2.88 in *Drosophila parabiopectinata*, the mean survival time varies from 36.5 ± 1.59 to 46.2 ± 2.08 and in *Drosophila biopectinata*, the differences fluctuate from 48.8 ± 1.62 to 53.5 ± 1.62 (**Table 1**).

Students t-test was performed to observe the variations in survival time among the individuals of two different isofemale lines and the values for different comparisons are presented in **Table 2**. **Table 2** although shows that in most of the comparison, the differences between two isofemale lines are statistically insignificant, however significant differences have been observed in some comparisons 1vs. 2, 3, 5, 9 & 10; 2vs. 3, 5, 9, 10; 3vs. 5, 9 & 10; 5vs. 10; 9 vs. 10. The data shown in **Table 1** and **Table 2** for inter-population variation in starvation resistance can possibly explain the required genetic and physiological changes underlying during inter-released stress.

Discussion

Desiccation and starvation resistance vary markedly among *Drosophila* species. The most extensive comparison has considered resistance in 22 species and related differences among species to their tropical/temperate origins and to their cosmopolitan/endemic status (*Van Herrewege & David, 1997*) In general, tropical species are less resistant to desiccation stress than temperate species but there are no clear patterns for endemism. Tropical species are also less resistant to starvation, which varied (at 25°C) from 171 h (*D. buzzatii*) to only 25 h (*D. sechellia*). The experiments undertaken to date suggest a robust association between starvation and desiccation resistance, and therefore common mechanisms underlying some of the variation in these traits. This has been demonstrated in *D. serrata* as well as in independently selected lines of *D. melanogaster* (*Blows & Hoffmann, 1993; Hoffmann & Parsons, 1993a; Harshman et al., 1999a*). It has also been observed in comparisons of isofemale lines of *D. melanogaster* (*Hoffmann, unpublished observation*). This association may stem partly from the contribution of glycogen to both traits (*Rose & Archer, 1996*). A comparison of *Drosophila* species (*Van Herrewege & David, 1997*) also indicates a positive correlation between these traits. This raises the issue of whether associations at the level of variation among species generally reflect similar patterns at the geographical and intra-population levels.

There is ample genetic variation for both starvation and desiccation resistance within populations of *D. melanogaster*. This is apparent from the rapid responses to laboratory selection for these traits (*Service et al., 1988; Hoffmann & Parsons, 1989a; Chippindale et al., 1996; Harshman & Schmid, 1998*). Moreover, high heritability estimates have been observed for both traits; estimates near 100% have been obtained for starvation resistance (*Service & Rose, 1985*) whereas for desiccation resistance estimates are around 60% (*Hoffmann & Parsons, 1989a*). High levels of genetic variation allow for large shifts in the mean resistance of populations. For instance, (*Chippindale et al., 1996, 1998*) observed increased levels of desiccation and starvation resistance in a population of *D. melanogaster* by 3–4 and 4–6 times, respectively and more recently different gene loci in genome of *D. melanogaster* have been identified for starvation resistance (*Mezey et al., 2005, Bublly and Loeschcke, 2005*).

For starvation, there is good evidence that an increase in the lipid content of adults underlies increased resistance to starvation. Some data suggest that this trait accounts for almost all the variation in starvation resistance. For instance, (*Chippindale et al. 1996*) scored lipid and starvation levels in different sets of lines

selected for starvation or changes in life history traits. They found a correlation close to one between starvation and lipid levels when all lines were considered. The lipid association has also been documented from a set of starvation-selection lines derived from a different base population (*Harshman et al., 1999a*), in comparisons of allozyme genotypes (*Oudman et al., 1994*), and the way in which lipid levels and starvation change with age (*Service, 1987*).

The results obtained from the present investigation are consistent with the assumption for *D. melanogaster* that long lived isofemale lines had greater resistance to various abiotic stresses including starvation (*Block and Wheeler, 1972*). The earlier experiments for stress tolerance have proved that lower metabolic rate alter the energy requirement of flies to lower level, (*Parson, 1987*). The death of flies under optimum temperature range occur due to loss of all body reserve especially lipids in presence of water. To overrule the possibility of other stresses like heat or cold causing death of flies besides starvation condition, a thermal range of 11°C was considered to be an important factor since all reserve exhaust at this temperature (*Joshi, 1997*) and hence during present study all experiments were performed at 25°C.

Table 1 shows remarkable difference in mean survival time of not only isofemale line from three inter-specific natural populations of *Drosophila* but also in isofemale line of intra-specific populations of each *Drosophila* species. The mean survival time was recorded to be the highest in *Drosophila malerkotiana*, than *Drosophila bipectinata* and the lowest in *Drosophila parabiptinata* under starvation conditions. These results resemble very much for distribution records of the three species collected in rainy season from different hot and humid forest regions of India. Since *Drosophila malerkotiana*, were caught in the highest number in comparison to the other two species under consideration, in other seasons the occurrence of lower number of all three species of *Drosophila* from natural populations is not only due to starvation condition but other environmental stress could have affected their distribution.

Though there has been a remarkable difference in mean survival time under starvation condition among inter-specific population of three *Drosophila* species, the statistical differences were insignificant in most of the cases; however significant variations were obtained in some case. This maintains that resistance to starvation is an additive genetic trait and populations therefore have potential to undergo rapid genetic changes in response to different environmental stresses (*Parson, 1983; Kristenson et al., 2011*). It has been observed that populations with more heterozygous genotype are more resistance to starvation (*Singh & Gupta, 1980*). The three *Drosophila* species also differ at the level of heterozygosity. The species of *Drosophila malerkotiana*, which is highly polymorphic for its genotype maintains highest survival under starvation, whereas *Drosophila parabiptinata* with comparatively lower heterozygosity have lowest survival time, the only exception to such assumption being *Drosophila bipectinata* which have less genotype polymorphism but better average survival rate than *Drosophila parabiptinata* (*Das et al., 1994; David et al., 1983; Hoffmann and Parson, 1989*).

It will be premature to conclude the exact reason for starvation tolerance in fructose sugar media, since this study has been carried out at inter-species level from natural population among three different species of *Drosophila* from *bipectinata* subgroup for the first time, and hence to elucidate the role of ecophysiological conditions and its genetic basis in different environmental stress including starvation, elaborate study will be of immense significance.

Acknowledgments

The authors are grateful to the Principal, Feroze Gandhi College, Raebareli for providing necessary facilities.

References

1. Bock I R and Wheeler M.R.(1972). *The D. melanogaster species group* University Texas publication studies genetics, **7213**: 1-102.
2. Blows, M. W. and Hoffmann, A. A.(1993). *The genetics of central and marginal populations of Drosophila serrata 1. Genetic variation for stress resistance and species borders*. Evolution, **47**: 1255–1270.
3. Bublik OA, Loeschcke V.(2005). *Correlated responses to selection for stress resistance and longevity in a laboratory population of Drosophila melanogaster*. J Evol Biol.;**18**(4):789-803.
4. Chippindale, A. K., Chu, T. J. F. and Rose, M. R.(1996). *Complex trade-offs and the evolution of starvation resistance in Drosophila melanogaster*. Evolution, **50**: 753–766.
5. Chippindale, A. K., Gibbs, A. G., Sheik, M., Yee, K. J., Djawdan, M., Bradley, T. J. and Rose, M. R.(1998). *Resource acquisition and the evolution of stress resistance in Drosophila melanogaster*. Evolution, **52**: 1342–1352.
6. Coyne, J. A., Bundgaard, J. and Prout, T. (1983). *Geographic variation of tolerance to environmental stress in Drosophila pseudoobscura*. Am Nat, **122**: 474–488.
7. David, J R, Allemand, R, Van Herrewage J, and Cohet Y(1983) *Ecophysiology: abiotic factors*. In: Ashburner, M., Carson, H. L. and Thompson, J. N. (eds)(1983). *The Genetics and Biology of Drosophila*, vol. **3**, pp. 105-170. Academic Press, London.
8. Das, A. Nayak, Sarita and Parida, B.B.(1994). *Intrapopulational variation in starvation tolerance in Indian D. melanogaster*. Proceeding of the National Academy of Sciences India **64** (B):51-56.
9. Gibbs, A.G., Chippindale, A.K. and Rose, M.R.(1987). *Physiological mechanisms of evolved desiccation resistance in Drosophila melanogaster*. J Exp Biol, **200**:1821-1832.
10. Gibbs A. G. (2002). *Lipid melting and cuticular permeability: new insights into an old problem*. J. Insect Physiol. **48**: 391–400. ([doi:10.1016/S0022-1910\(02\)00059-8](https://doi.org/10.1016/S0022-1910(02)00059-8)),
11. Gompel, N., Prud'homme, B.(2009). *The causes of repeated genetic evolution*. Developmental Biology **332**, 36-47.
12. Gupta, J. P. and Panigrahy, K.K. (1990). *Chromosomal polymorphism in Indian populations of Drosophila bipectinata* duda, Genetica, **82**:45-49.
13. Harshman, L. G. and Schmid, J. L.(1998). *Evolution of starvation resistance in Drosophila melanogaster: aspects of metabolism and counter-impact selection*. Evolution, **52**: 1679–1685.
14. Harshman, L. G., Hoffmann, A. A. and Clark, A. G. (1999a). *Selection for starvation resistance in Drosophila melanogaster: physiological correlates, enzyme activities and multiple stress responses*. J Evol Biol, **12**: 370–379
15. Hoffmann ,A.A., Harshman L.G.(1999). *Desiccation and starvation resistance in Drosophila: patterns of variation at the species, population and intrapopulation levels*.Heredity (Edinb).;**83** (Pt 6):637-43.
16. Hoffmann, A. A. and Parsons, P.A.(1989a). *An integrated approach to environmental stress tolerance and life-history variation: desiccation tolerance in Drosophila*. Biol J Linn Soc, **37**: 117–135.
17. Hoffmann, A. A. and Parsons, P. A.(1989b). *Selection for increased desiccation resistance in Drosophila melanogaster: additive genetic control and correlated responses for other stresses*. Genetics, **122**: 837–845, 1989b.

18. Hoffmann, A. A. and Parsons, P. A.(1993a). *Direct and correlated responses to selection for desiccation resistance – a comparison of Drosophila melanogaster and D. simulans*. J Evol Biol, **6**: 643–657.
19. Hoffmann, A. A., Sorensen, J. G. and Loeschcke, V.(2003). *Adaptation of Drosophila to temperature extremes: bringing together quantitative and molecular approaches*. J. Therm. Biol. **28**, 175-216.
20. Joshi, A.(1997). *Laboratory studies of density dependent selection: adaptation to crowding in D. melanogaster*. Current Science **72**:555-562.
21. Karan, D., Dahiya, N., Munjal, A.K., gibert, P., Moretear, B., Parash, R. and David, J. R.(1998). *Desiccation and starvation tolerance of adult Drosophila-opposite latitudinal clines in natural populations of three different species*. Evolution, **52**:825-831.
22. Kellermann, V. M., van Heerwaarden, B., Sgrò, C. M. and Hoffmann, A. A.(2009). *Fundamental evolutionary limits in ecological traits drive Drosophila species distributions*. Science **325**, 1244-1246.
23. Kumar, Ajai, Saxena, Shivani and Singh, Tanima(2004). *Chromosomal Organization in India population of D. Malerkotliana* . Parshad & Paika. Nucleus, **47**(3):175-180.
24. Kristenson, T.N., Loeschcke, V. Bilde, T. Halfmann, A.A., Sgroc, Noreikiene, K. Ondresik M and Bechsgard, J.S. (2011). *No embreeding depression for Low Temperature Developmental acclimation across multiple Drosophila species*. Evolution, **65** (11):3195-3201.
25. McKenzie, J.A. and Parsons, P.A.(1974). *Microdifferentiation in a natural population of D. melanogaster to alcohol in the environment*. Genetics, **77**: 385-394.
26. Mezey, J. G., Houle, D. & Nuzhdin, S. V.(2005). *Naturally segregating quantitative trait loci affecting wing shape of Drosophila melanogaster*. Genetics, **169**: 2101–2113.
27. Oudman, L., van Delden, W., Kamping, A., Bijlsma, R.(1994). *Starvation resistance in Drosophila melanogaster in relation to the polymorphisms at the Adh and Gpdh loci*. J. Insect Physiol. **40**(8): 709-713.
28. Parsons P.A.(1983). *The evolutionary biology of colonizing species*. Cambridge University Press, New York, p.262
29. Parsons P.A.(1987). *Evolutionary rates under environmental stress*. Evolutionary Biology, **21**: 311 – 357.
30. Parsons P.A.(1991). *Biodiversity conservation under global climatic change: The insect Drosophila s a biological indicator?* Global Ecol. Biogeogr. Lett. **1**, 77±83.
31. Prakash, S., Caldwell, J.C., Eberl, D.F., Clandinin, T.R.(2005). *Drosophila N-cadherin mediates an attractive interaction between photoreceptor axons and their targets*. Nat. Neurosci. **8**(4): 443--450.
32. Panigrahy, K.K.(1984). *Ecogeographic differentiation of species and chromosomal inversions in Indian populations of Drosophila* : Ph.D thesis, Banaras Hindu University, Varanasi.
33. Parkash, R., Yadav, J.P. and Vashist, M.(1994). *Electrophoretic and cryptic genic variability in natural populations of Zaprionus indianus*. Proceedings Indian National Science Academy **60**: 75-82.
34. Parkash, R., A.K.Munjal, and D. Karan(1998). *Thermal adaptive significance of ADH and EST-6 allozymes in Indian geographical populations of Drosophila melangoaster*, J. Zool. Syst. Evol. Research. **36**:147-152.
35. Karan.D., and Parkash., R.(1998). *Desiccation tolerance and starvation resistance exhibit opposite latitudinal clines in Indian geographical populations of Drosophila kikkawai*, Ecological Entmology.**23**: 391-396,

36. Parkash,R. and A. K. Munjal(1999). *Climatic selection of starvation and desiccation resistance in populations of some tropical drosophilids*, J. Zoo. Syst. Evol. Research, Germany **37**: 195-202.
37. Parkash, R., Aggarwal, D. D., Kalra, B. (2011). *Coadapated changes in energy metabolites and body color phenotypes for resistance to starvation and desiccation in latitudinal populations of D. melanogaster*. Evolutionary Ecology **25**: doi: 10.1007/s10682-011-9482-x, 2011
38. Parkash, R., Chahal, J., Sharma, V., Dev, K.(2011). *Adaptive associations between total body color dimorphism and climatic stress related traits in a stenothermal circumtropical Drosophila species*. Insect Science. **18**: doi: 10.1111/j.1744-7917.2011.01426.x.
39. Rose, M. R. and Archer, M. A.(1996). *Genetic analysis of mechanisms of aging*. Curr Opin Gen Dev, **6**: 366–370.
40. Service, P. M. and Rose, M. R.(1985). *Genetic covariation among life-history components: The effect of novel environments*. Evolution, **39**: 943–945.
41. Service, P. M., Hutchinson, E. W. and Rose, M. R.(1988). *Multiple genetic mechanisms for the evolution of senescence in Drosophila melanogaster*. Evolution, **42**: 708–716.
42. Service P.M.(1987). *Physiological mechanisms of increased stress resistance in D. melanogaster selected for postponed senescence*, Physiological Zoology, **60**:321-326.
43. Singh, B.K. and Gupta, J. P.(1980). *Pattern of chromosomal polymorphism in D. jambulina parshad and paika*. Japan Journal of Genetics, **55**:81-90.
44. Stern, D.L., and Orgogozo, V. Science **323**, 746–751, 2009.
45. Telonis-Scott, M., Guthridge, K. M. and Hoffmann, A. A.(2006). *A new set of laboratory-selected Drosophila melanogaster lines for the analysis of desiccation resistance: response to selection, physiology and correlated responses*. J. Exp. Biol.**209**, 1837-1847.
46. van Herrewege, J., David, and J.R.(1997). *Starvation and desiccation tolerances in Drosophila: Comparison of species from different climatic origins*. Ecoscience **4**, 151–157, 1997

Table:1

Time of survival and mean survival time in each isofemale line of *bipectinata*
Subgroup of the genus *Drosophila*, exposed to starvation condition in fructose sugar media.

Isofemale Line	Male Individuals	Survival Time (in Hrs) \pm SE	Isofemale Line	Male Individuals	Survival Time (in Hrs) \pm SE
<i>1-Drosophila malerkotiana Raebareli</i>	1	40 \pm 3.75	<i>2-Drosophila malerkotiana Salon</i>	1	42 \pm 3.28
	2	35 \pm 2.18		2	34 \pm 1.86
	3	42 \pm 3.92		3	44 \pm 1.58
	4	33 \pm 1.55		4	36 \pm 1.56
	5	46 \pm 4.39		5	43 \pm 3.38
	6	52 \pm 1.81		6	55 \pm 2.30
	7	50 \pm 2.09		7	50 \pm 2.39
	8	45 \pm 3.27		8	48 \pm 1.21
	9	54 \pm 1.69		9	53 \pm 2.09
	10	38 \pm 3.37		10	44 \pm 3.12
	mean \pm SE	43.5 \pm 2.26		mean \pm SE	44.9 \pm 2.14
Isofemale Line	Male Individuals	Survival Time (in Hrs) \pm SE	Isofemale Line	Male Individuals	Survival Time (in Hrs) \pm SE
<i>3-Drosophila malerkotiana Unchahar</i>	1	39 \pm 3.00	<i>4-Drosophila malerkotiana Bachhrawan</i>	1	49 \pm 2.52
	2	45 \pm 3.53		2	55 \pm 5.12
	3	40 \pm 1.61		3	50 \pm 2.32
	4	36 \pm 1.56		4	46 \pm 1.56
	5	44 \pm 3.51		5	54 \pm 2.24
	6	51 \pm 2.44		6	61 \pm 4.52
	7	49 \pm 2.25		7	59 \pm 1.95
	8	52 \pm 2.03		8	62 \pm 2.23
	9	55 \pm 2.41		9	65 \pm 2.06
	10	54 \pm 3.39		10	77 \pm 1.44
	mean \pm SE	46.5 \pm 2.11		mean \pm SE	57.8 \pm 2.88
Isofemale Line	Male Individuals	Survival Time (in Hrs) \pm SE	Isofemale Line	Male Individuals	Survival Time (in Hrs) \pm SE
<i>5-Drosophila Bipectinata Raebareli</i>	1	44 \pm 3.47	<i>6-Drosophila Bipectinata Unchahar</i>	1	63 \pm 5.08
	2	46 \pm 3.73		2	47 \pm 3.15
	3	43 \pm 3.25		3	50 \pm 3.65
	4	47 \pm 2.85		4	51 \pm 3.52
	5	46 \pm 3.12		5	57 \pm 3.86
	6	54 \pm 5.11		6	60 \pm 2.99
	7	49 \pm 3.68		7	54 \pm 3.24
	8	58 \pm 4.59		8	52 \pm 4.22
	9	51 \pm 2.25		9	53 \pm 3.31
	10	50 \pm 3.76		10	48 \pm 3.34
	mean \pm SE	48.8 \pm 1.62		mean \pm SE	53.5 \pm 1.62

Isofemale Line	Male Individuals	Survival Time (in Hrs) \pm SE	Isofemale Line	Male Individuals	Survival Time (in Hrs) \pm SE
<i>7-Drosophila</i>	1	40 \pm 1.43	<i>8-Drosophila</i>	1	42 \pm 4.61
<i>parabipectinata</i>	2	39 \pm 1.76	<i>parabipectinata</i>	2	35 \pm 2.39
<i>Raebareli</i>	3	33 \pm 1.56	<i>Salon</i>	3	40 \pm 1.96
	4	32 \pm 1.83		4	31 \pm 2.45
	5	42 \pm 3.32		5	44 \pm 4.23
	6	41 \pm 3.42		6	52 \pm 2.64
	7	32 \pm 2.62		7	35 \pm 2.24
	8	30 \pm 2.17		8	32 \pm 2.69
	9	33 \pm 2.58		9	34 \pm 2.58
	10	43 \pm 2.57		10	27 \pm 1.81
	mean \pm SE	36.5 \pm 1.59		mean \pm SE	37.2 \pm 2.32

Isofemale Line	Male Individuals	Survival Time (in Hrs) \pm SE	Isofemale Line	Male Individuals	Survival Time (in Hrs) \pm SE
<i>9-Drosophila</i>	1	39 \pm 2.29	<i>10-Drosophila</i>	1	58 \pm 2.92
<i>parabipectinata</i>	2	34 \pm 2.58	<i>parabipectinata</i>	2	39 \pm 3.46
<i>Unchahar</i>	3	41 \pm 3.24	<i>Bachhrawan</i>	3	43 \pm 3.13
	4	32 \pm 1.17		4	41 \pm 4.08
	5	45 \pm 2.51		5	45 \pm 2.65
	6	51 \pm 2.11		6	52 \pm 3.02
	7	49 \pm 1.77		7	49 \pm 4.37
	8	44 \pm 2.52		8	44 \pm 2.72
	9	53 \pm 2.03		9	53 \pm 3.62
	10	37 \pm 3.38		10	38 \pm 3.80
	mean \pm SE	42.5 \pm 2.26		mean \pm SE	46.2 \pm 2.08

Figure:1

<- Species Group ->

Figure 1: Mean Survival time of each population in *bipectinata* subgroup of the genus *Drosophila* *malerkotiiana*, *D. bipectinata*, *D. parabipectinata*, Bars on histogram represent SE for mean survival time.

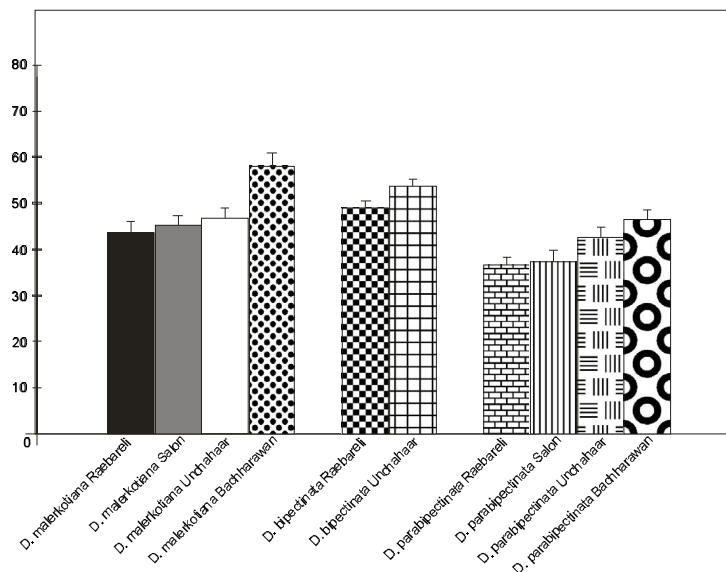


Table2:

The t-value (above diagonal) and associated probability (below diagonal) between the mean survival time of two given isofemale line of three species of *biplectinata*-subgroup of the genus *Drosophila* in fructose sugar media.

	1	2	3	4	5	6	7	8	9	10
1	---	- 0.45 (20)	- 0.97 (20)	- 3.90 (20)	- 1.97 (20)	- 3.49 (20)	2.48 (20)	1.89 (20)	0.31 (20)	- 0.88 (20)
2	<0.10*	---	-0.53 (20)	- 3.59 (20)	- 1.50 (20)	- 3.10 (20)	3.08 (20)	2.37 (20)	0.77 (20)	- 0.43 (20)
3	<0.10*	<0.10*	---	- 3.16 (20)	- 0.89 (20)	- 2.55 (20)	3.70 (20)	2.88 (20)	1.29 (20)	0.10 (20)
4	>0.10	>0.10	>0.10	---	2.78 (20)	1.26 (20)	6.31 (20)	5.40 (20)	4.05 (20)	3.26 (20)
5	<0.10*	<0.10*	<0.10*	>0.10	---	- 2.08 (20)	5.59 (20)	4.10 (20)	2.34 (20)	1.62 (20)
6	>0.10	>0.10	>0.10	>0.10	>0.10	---	7.11 (20)	5.42 (20)	3.89 (20)	2.69 (20)
7	>0.10	>0.10	>0.10	>0.10	>0.10	>0.10	---	- 0.24 (20)	- 2.12 (20)	- 3.63 (20)
8	>0.10	>0.10	>0.10	>0.10	>0.10	>0.10	<0.10	---	- 1.59 (20)	- 2.80 (20)
9	<0.10*	<0.10*	<0.10*	>0.10	>0.10	>0.10	>0.10	>0.10	---	- 1.20 (20)
10	<0.10*	<0.10*	<0.10*	>0.10	<0.10*	>0.10	>0.10	>0.10	<0.10*	---

*Significant, the values in parentheses indicate the degree of freedom.

A STUDY OF THE MANAGERIAL SKILLS OF SCHOOL PRINCIPALS AND PERFORMANCE OF SCHOOLS

*Soma Mukherjee**

ABSTRACT

The need for effective management is all pervasive. Investments in terms of time and monetary resources are of little use if the same is not managed and administered effectively. Those at the senior managerial positions of educational institutions have the prime responsibility of running a successful system so as to ensure proper and smooth functioning of the organization. This study is aimed to explore whether there is any significant relationship between a School Principal's managerial effectiveness and School's performance. The study is summation of a systematic quantitative analysis of data collected from 527 respondents (comprised of school teachers, Heads of departments and vice-principals) from government and Private schools in Ghaziabad and Mathura districts of Uttar Pradesh. Regression analysis and tests of significance have been used as the corner stone for this study. The study reveals an insightful understanding of what works for Heads of schools in order to successfully manage their institutions.

Keywords: communication skill, linear regression, performance parameter, t-test,

Introduction

For decades, Principals have been recognized as important contributors to the effectiveness of schools. In an era of shared decision-making and management in schools, leadership matters. Principals constitute the core of the leadership team in schools.

We know from existing effective schools research that “effective Principals influence a variety of school outcomes, including student achievement, through their recruitment and motivation of quality teachers, their ability to identify and articulate school vision and goals, their effective allocation of resources, and their development of organizational structures to support instruction and learning” (Hornig, Kalogrides & Loeb 2009, p.1).

The quality of a Principal effects a range of school outcomes including teachers' satisfaction and their decisions about where to work, parents' perceptions about the schools their children attend, and, ultimately, the academic performance of the school. School Principal's job is complex and multifaceted, and the effectiveness of principals depends on their level of experience, their sense of efficacy on particular kinds of tasks, and their allocation of time across daily responsibilities

Many a time, Principals' subjective evaluations of teachers may offer valuable information on teacher performance beyond what can be captured by student test scores alone.

There is little doubt that school leaders matter for school success. A large number of studies spanning the last three decades link high quality leadership with positive school outcomes, including student achievement.

* **Soma Mukherjee** is a Research Scholar at Mewar University, Chittorgarh, Rajasthan, India.

This study would focus on the extent of the impact of school Principal's managerial skills on school's performance, and identify the importance of different skills needed for Principals to perform their job effectively. Furthermore, the study would also provide systematic evidence of the linkages between school leader efficacy and school outcomes, including student achievement gains and teacher satisfaction.

Statement of the problem

The present study focuses on establishing the relationship between schools Principal's managerial effectiveness and school's performance based on key performance indicators.

Specifically, the study aims to answer the following key questions –

- a) How Principal's efficacy predicts key school outcomes, including student achievement gains, teacher satisfaction, and parents' assessments of school performance?
- b) Which are the key managerial skills that truly drive Principal's overall performance?

Research Objectives

In order to answer the key questions mentioned above, the study aims to understand the impact of managerial skills of Principals and Heads of schools in terms of their effectiveness in relation to the school's achievements.

Specifically the research covers the following areas:

- a) Relationship and impact of Principal's managerial efficacy on school's success
- b) The key managerial skills required to be a successful Principal of schools
- c) The relative importance of these skills with respect to their effectiveness
- d) Identification of the ideal mix of managerial skills in order to be successful as a Principal

Research Hypothesis

The study would test out the following key null and alternative hypothesis:

Null Hypothesis: Successful performance of a school depends on the managerial skills and effectiveness of the Principal of the school

Alternative Hypothesis: Successful performance of a school is independent of the managerial skills and effectiveness of the principal of the school

Scope of the Research

Variables of the study:

To establish the relation between a school's overall performance and Principal's efficacy, Principal's overall performance has been used as independent variable and overall school performance has been used as the dependent variable in a linear regression model.

Further, sub-parameters of Principal's performance ratings were regressed with Principal's overall performance (as dependent) to achieve their relative importance.

Population

The population for this study consisted of teachers of government and private schools (having classes till standard XII) in Ghaziabad and Mathura districts in the state of Uttar Pradesh.

Sample

A total of 527 respondents having a mix of teachers, Heads of departments and Vice-Principals were interviewed using a quantitative structured survey questionnaire in order to record responses for statistical analysis to assess importance of various managerial skills.

Findings of the study

At the start of the analysis, linear regression was run between school's overall performance (dependent variable) and Principal's performance (independent variable). The analysis gave the following results:

Table: 1**Analysis Summary**

Model	R	R Squared	Adjusted R Square	Std. Error of the Estimate
1	.802(a)	.643	.642	.833

Predictors: (Constant, Overall performance of the Principal of the school)

Table:2**Regression Analysis Coefficients**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.367	.151		9.075	.000
	Overall performance of the principal of the school	.797	.026	.802	30.721	.000

Dependent Variable: School's Overall Performance

With an R^2 of 0.64, the above analysis clearly shows a strong model fitment between school's performance and Principal's efficacy. Sig value of 0.000 shows strong significance of the model. Further, a t-test for significance also reveals significant difference between school's performances depending on Principal's efficacy (Sig – 2 tailed of 0.000).

A further exploration to understand what really is perceived as school's performance; a regression analysis was run between school's overall performance and performance scores on other key parameters – Overall results and academic performance of students passing out of class 10th, – Overall results and academic performance of students passing out of class 12th, Teachers' satisfaction and motivation level and school's involvement in co-curricular and extra curricular events.

With an R^2 of 0.506, the model revealed that there is strong linkage between overall ratings and the ratings for the above mentioned sub-parameters.

Table:3
Analysis Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.712(a)	.506	.502	.982

Predictors: (Constant), Co-curricular and extra-curricular activities, Overall results and academic performance of students passing out of class 10th , Overall results and academic performance of students passing out of class 12th, Teachers' satisfaction and overall motivation

The relative importance of Beta values uncovers that academic performance of students passing out of class 12th (0.294, see **Table 4**) and 10th (0.242) are the most important parameters driving overall ratings for school (with teachers as survey respondents). This is followed by ratings on teachers' satisfaction and motivation (0.166) and school's involvement in extra-curricular/co-curricular events (0.155).

Table:4
Regression Analysis Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.023	.215		4.755	.000
	Overall results and academic performance of students passing out of class 10th	.258	.043	.242	5.943	.000
	Overall results and academic performance of students passing out of class 12th	.346	.053	.294	6.513	.000
	Teachers' satisfaction and motivation overall	.156	.047	.166	3.338	.001
	Co-curricular and extra-curricular activities	.144	.043	.155	3.346	.001

Dependent Variable: School's Overall Performance

Key Drivers of Overall Ratings for Principal's Performance

The next step in this analysis was to find out the performance parameters , which are key drivers of overall ratings for Principal's performance. To come up with this insight, regression analysis was run with Principal's overall performance and sub-parameters like Administrative Skills, Communication Skills, Cognitive Skills and Supervisory Skills.

Table:
5 Analysis Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.736(a)	.541	.538	.952

Predictors: (Constant), Supervisory skills, Administrative Skills, Cognitive skills, Communication skills

Table:6
Regression Analysis Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.497	.184		8.144	.000
	Administrative Skills	.084	.041	.084	2.061	.040
	Communication skills	.224	.047	.257	4.798	.000
	Cognitive skills	.189	.044	.211	4.294	.000
	Supervisory skills	.277	.042	.289	6.555	.000

Dependent Variable: Overall performance of the Principals of the school

The analysis in **Table 6** clearly shows that Supervisory Skills (Beta 0.289) and Communication Skills (0.257) are the two most important skill-set required for managerial effectiveness of Principals. Cognitive skills (with Beta of 0.211) is also a very important factor.

Within Supervisory skills, *appropriate delegation of work and responsibilities and carrying out appropriate performance appraisal of staff members* are the two most important aspects (as shown in the **Table 7**).

Table:7
Regression Analysis Coefficients (Regression R² = 0.534)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.573	.189		8.316	.000
	Ability and extent of training, coaching and mentoring	.154	.047	.165	3.294	.001
	Appropriate delegation of work and responsibilities	.306	.050	.299	6.084	.000
	Carrying out appropriate performance appraisal of staff members	.261	.054	.287	4.830	.000
	Imparting discipline in the school	.064	.037	.068	1.735	.083

Dependent Variable: Supervisory skills

A similar ranking of communication skills sub-factors in order of their importance disclosed that the most important aspect of communication is *the ability to give clear instruction and information* followed by *listening skills and getting involvement of staff members in decision making* and *the ability to give honest constructive feedback to staff members*.

Within the cognitive skills umbrella, the three most important sub-parameters that came up in the analysis were- a) *Identification and acknowledgement of issues and problems* b) *Ability to make correct decisions and assess associated risks* and c) *Identification and implementation of appropriate solution to problems.*

Conclusions and Implications of the study

The study clearly reveals a strong relationship between performance of a school and the managerial effectiveness of its principal, where the latter is the driver of the former. Perception about a school's performance is primarily driven by the academic results of class 12th and 10th.

Principal's managerial effectiveness is primarily driven by Supervisory Skills, followed by Communication Skills and Cognitive Skills.

Some of the key sub-parameters within these areas are *appropriate delegation of work and responsibilities, carrying out appropriate performance appraisal of staff members, the ability to give clear instruction and information* and by *listening skills and getting involvement of staff members in decision making.*

The study acts as a reference guide for Principals of schools so as to help them prioritize their focus areas to become good managers, and in turn good Principals, to be able to drive the success of schools.

References

1. Beteille, Tara, Demetra Kalogrides, and Susanna Loeb (2009). *Effective Schools: Managing the Recruitment, Development, and Retention of High-Quality Teachers*. CALDER Working Paper 37. Washington, DC: The Urban Institute.
2. Chakraborty, S.S.(2004). *Managerial Effectiveness and Quality of Work Life*. India Insights , McGraw Hill Education Publication
3. Horng, Eileen Lai, Demetra Kalogrides, and Susanna Loeb (2009). *Principal Preferences and the Uneven Distribution of Principals Across Schools*, CALDER Working Paper 36. Washington, DC: The Urban Institute..
4. Horng, Eileen Lai, Daniel Klasik, and Susanna Loeb (2009). *Principal Time-Use and School Effectiveness*. CALDER Working Paper 34. Washington, DC: The Urban Institute.
5. Kumar, Sunil(2002). *Managerial Effectiveness* , New Delhi
6. Mainiero, Tromley (2006). *Developing Managerial Skills In Organizational Behavior* , Davies Black Publishing
7. McGrath , E .H.(2011). *Basic Managerial Skills For All* ,PHI Learning Private Ltd 2011.
8. Patel, I.J.,and M.B. Buch eds.(1968) .*Readings in In-service Education*, Sardar Patel University Publication.
9. Rice, Jennifer King(2010). *Principal Effectiveness and Leadership in an era of Accountability: What Research Says?* CALDER Working Paper 8. Washington, DC: The Urban Institute.

Websites

1. www.hrdpress.com/MEP
2. www.ncte-india.org
3. whc.unesco.org/uploads/activities/documents/activity-331-19.doc